MACHINE DESIGN

November 1954

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NONMETALLIC GASK

Contents, page 3

Take this common sense approach to PUMPS

Save Time, Money, Trouble

Get specific engineering help

You'll find it pays off in hard cash to standardize on reliable, low maintenance Allis-Chalmers pumps for all your needs. That's because your A-C representative is an experienced, highly qualified engineer who will give you full cooperation at every step of the way—from planning to purchasing to production. Being a specialist in individual pump applications, as well as OEM design and production problems, he can frequently make valuable suggestions which result in substantial savings in time, money and effort — improved performance of your product.

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PUMPS

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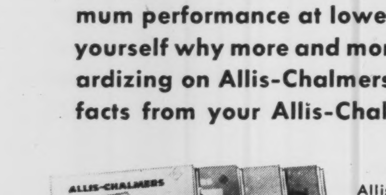

For literature on Allis-Chalmers
FHP Package Pumps get Bulletin 52B7529 . . .
Electrifugal Pumps, Bulletin 52B6140 . . .
Supporting Adaptor Pumps, Bulletin 52B6083
. . . Ver ical Mounted Pumps, Bulletin 52B6975.
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THE PROFESSIONAL JOURNAL
FOR ENGINEERS AND DESIGNERS

MACHINE DESIGN

NOVEMBER 1954
Vol. 26—No. 11

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Over the Board

STF²I

Around our offices, the regular "feature departments" in the magazine have acquired short names all their own. For instance, "Scanning the Field for Ideas" is commonly known as "Scanning"; "Men of Machines" is just plain "Men" (written by our gal editor, Jane Smith, by the way); and "New Machines" for some esoteric reason lost in the dim, dark past is often called "Listings." But now one of our staff members has come up with a new idea—symbols. A few are already used: "Contemporary Design" is *CD*, "New Parts and Materials" is *NP*, etc. But we hate to think of the effect. Someone might even want to make up an Equation (see Contents page for Nomenclature):

$$MD = O_tB + ENR\ (STF^2I) + CD(D^2) + \ldots + SR(NM) \quad \ldots\ldots (1)$$

As for us, it's Friday, so the most apt mathematical expression for our collective state of mind is summed up by *TGIF*. By the way, if you can't figure out all of this high-class math just drop us a postcard; we'll be happy to explain.

This Month's Cover

Printing paper may have its uses, but we don't believe that it would make a good gasket material. So we don't advise cutting out any of George Farnsworth's realistic art work on this month's cover for practical use. George has attempted to give an impression of the wide range of materials that are used for gaskets—among them rubber, cork, fiber, asbestos—and a few of the many shapes. For an even better idea of what's involved in gasket selection and use, you might turn to Page 157.

MACHINE DESIGN
November

Golf Clubs to Slide Rules

Engineering seems to be the favorite profession among caddies. At least, Howard Preston, a newspaper columnist, reports that 75 per cent of the caddies interviewed for scholarships by the Cleveland District Golf Association prefer engineering. And if you were to make a similar survey among engineers you'd probably find that 75 per cent prefer golf. One might say that the pattern, at least among some successful members of our profession, is golf to golf in one generation.

Are You Ept?

After a recent ramble through a few pages of the dictionary, we've decided that English is a most peculiar language. We got into the words starting with "in" and then turned to the "un" section. About the only logical conclusion we could draw from the excursion is that engineers, in addition to their professional qualifications, should always be couth, kempt, ept and ebriated.

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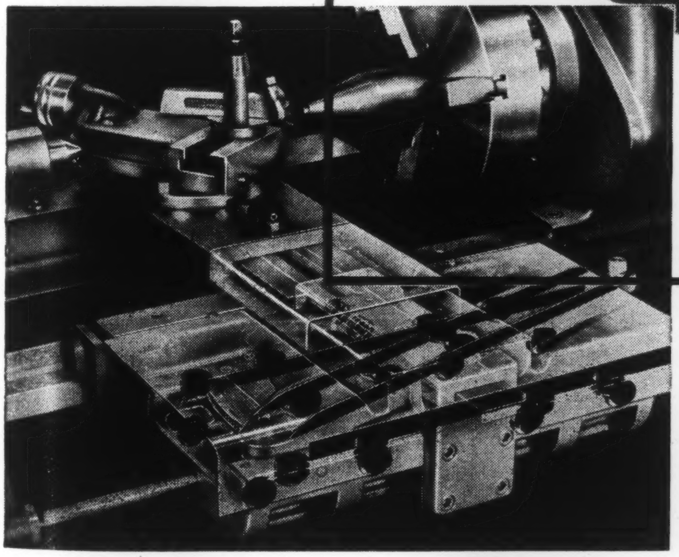

Twenty New Departure ball bearings are used in the Monarch Machine Tool Company's antifriction bearing taper attachment. There are 12 single-row bearings, 8 double-row bearings. All are permanently lubricated.

Many advantages of the Monarch lathe taper attachment are—according to its maker—the result of New Departure **ball** bearings. For by their use, backlash, friction and lost motion are almost entirely eliminated . . . smoother, more accurate tapers are possible. And Monarch's taper attachment takes heavy cuts even when boring or turning acute angles, for **ball** bearings give rigid support under both radial and thrust loads.

Call your New Departure sales engineer. Have him show you how New Departure ball bearings make a good product *even better!*

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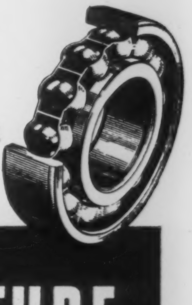

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Engineering News Roundup

Russian Engineers Start Learning Young

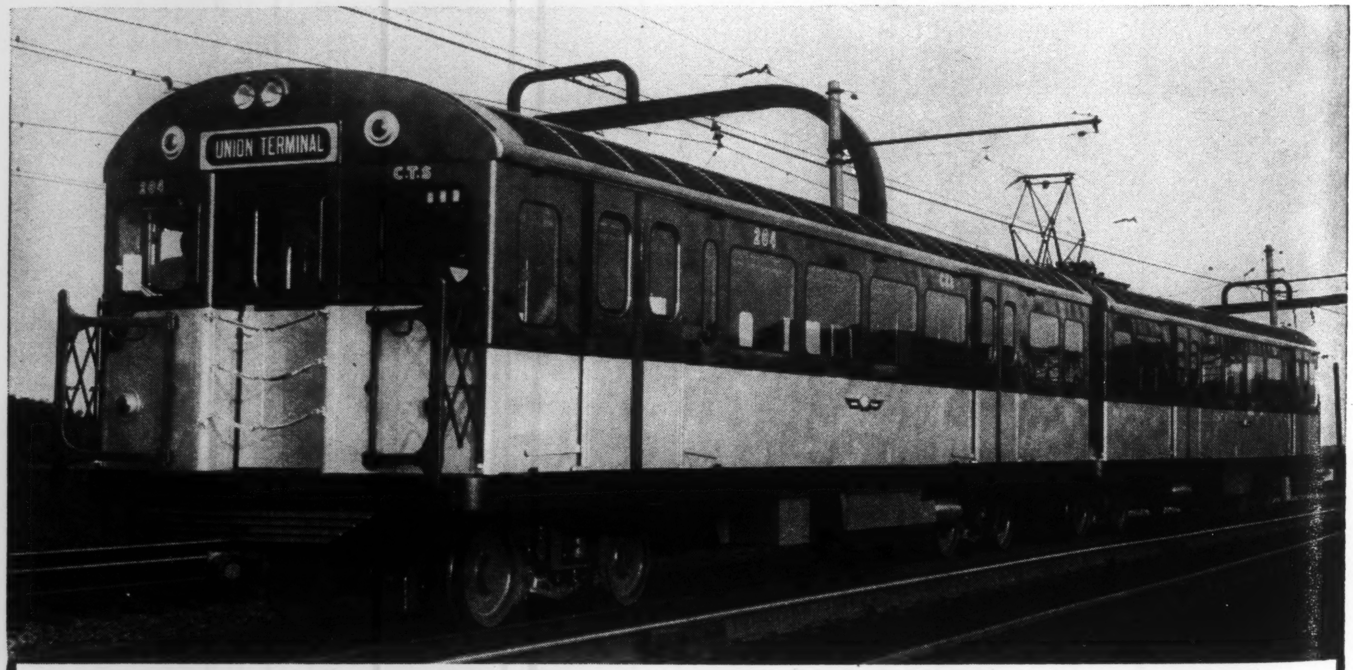
In a paper presented at the recent Milwaukee ASME meeting, Dr. M. H. Trytten of the Engineering Manpower Commission pointed out some interesting facts regarding Russian engineering education.

According to Trytten, Russian children enter kindergarten at the age of three. Reading is taught so that they are able to read upon entering elementary school.

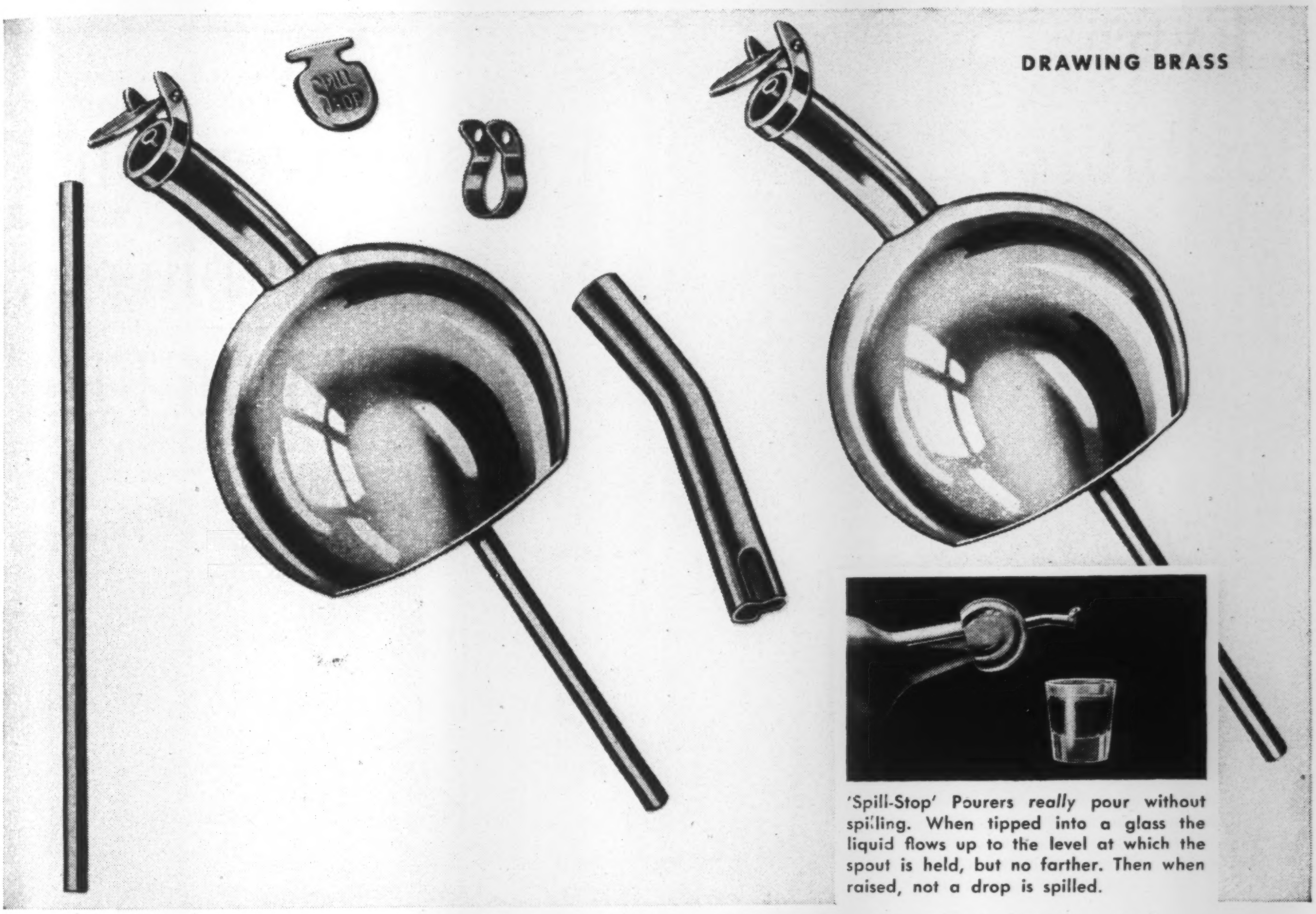
Elementary schooling is of 7 years' duration. About 32 per cent of the curriculum is devoted to technical subjects. These subjects include arithmetic, algebra, geometry, physics and the elements of chemistry.

After elementary school, the student may enter a secondary school or a technical school. In the secondary school there are no electives. About 40 per cent of the curriculum is devoted to science and mathematics. Technical schools train technicians with subprofessional status in three and four-year courses of study. Enrollment in these schools was reported to be over 4½ million in 1953-1954. Of the 760,000 graduates, 50,000 were subprofessional engineers.

About 900 institutions of higher learning exist in Russia. More than 50,000 engineers were graduated in 1952, according to the report. In the United States in 1954, only



RAPID TRANSIT for Clevelanders will become a reality when these new blue and silver trains begin operation in early 1955. Said to be the last word in transportation, the cars are being built by the St. Louis Car Co. for the Cleveland Transit System. Each car, powered by four 55-hp motors, is rated at a top speed of 47 mph. One-knob (control handle) control automatically controls power feed in 135 steps as well as dynamic and air braking. Car bodies are aluminum reinforced with corrosion-resistant Cor-ten steel. Wide picture windows are purposely permanently sealed! Ventilation and heating are provided by an electronic system designed by Minneapolis-Honeywell



'Spill-Stop' Pourers *really* pour without spilling. When tipped into a glass the liquid flows up to the level at which the spout is held, but no farther. Then when raised, not a drop is spilled.

BALL OF CHROME DOME and Gold Dome Pourers is made of Formbrite Drawing Brass, either chromium-plated or gold-plated over bright nickel. Tubing is supplied by French Small Tube Branch, an Anaconda subsidiary. Cap and hinge material is furnished by Anaconda's Kenosha Branch.

"When it comes to finishing these 'Spill-Stop' Pourers, there's no comparison between Formbrite and ordinary drawing brass"

—says Spill-Stop Mfg. Co.

Spill-Stop* Manufacturing Company is enthusiastic in its praise for Formbrite*—Anaconda's new drawing brass.

They say, "We've used Formbrite for the ball of our Chrome Dome* and Gold Dome Pourers for two years. We save enough in *finishing costs* to sell our Pourers now at the same price we did in 1946 — despite increases in the cost of materials and labor."

Spill-Stop goes on to say, "We find Formbrite fabricates almost as readily as the softest draw brass . . . the close tolerance to which your mill has held the gage has contributed greatly to the ease of fabrication."

Yet Formbrite costs no more than the ordinary drawing brass Spill-Stop had been using. And Formbrite very often saves more than the metal itself costs.

WHY FORMBRITE CUTS FINISHING COSTS

Formbrite has a superfine grain. Special methods of rolling and annealing produce a grain structure so fine that often a simple color buff will bring it to a bright, lustrous finish.

Formbrite is also harder, stiffer, springier and more scratch-resistant . . . yet it is surprisingly ductile, readily stamped, formed, drawn and embossed. And Formbrite plates beautifully.

FREE SAMPLE

Formbrite is available in sheets, strips and coils — in all commercial widths and gages. Millions of pounds of this superior drawing brass have been made, sold and satisfactorily fabricated.

Want more proof? Send for a free sample of Formbrite. Try it in your polishing room. See for yourself how quickly and easily Formbrite polishes. Also ask for Publication B-39 which gives forming and finishing suggestions. Write: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 5491

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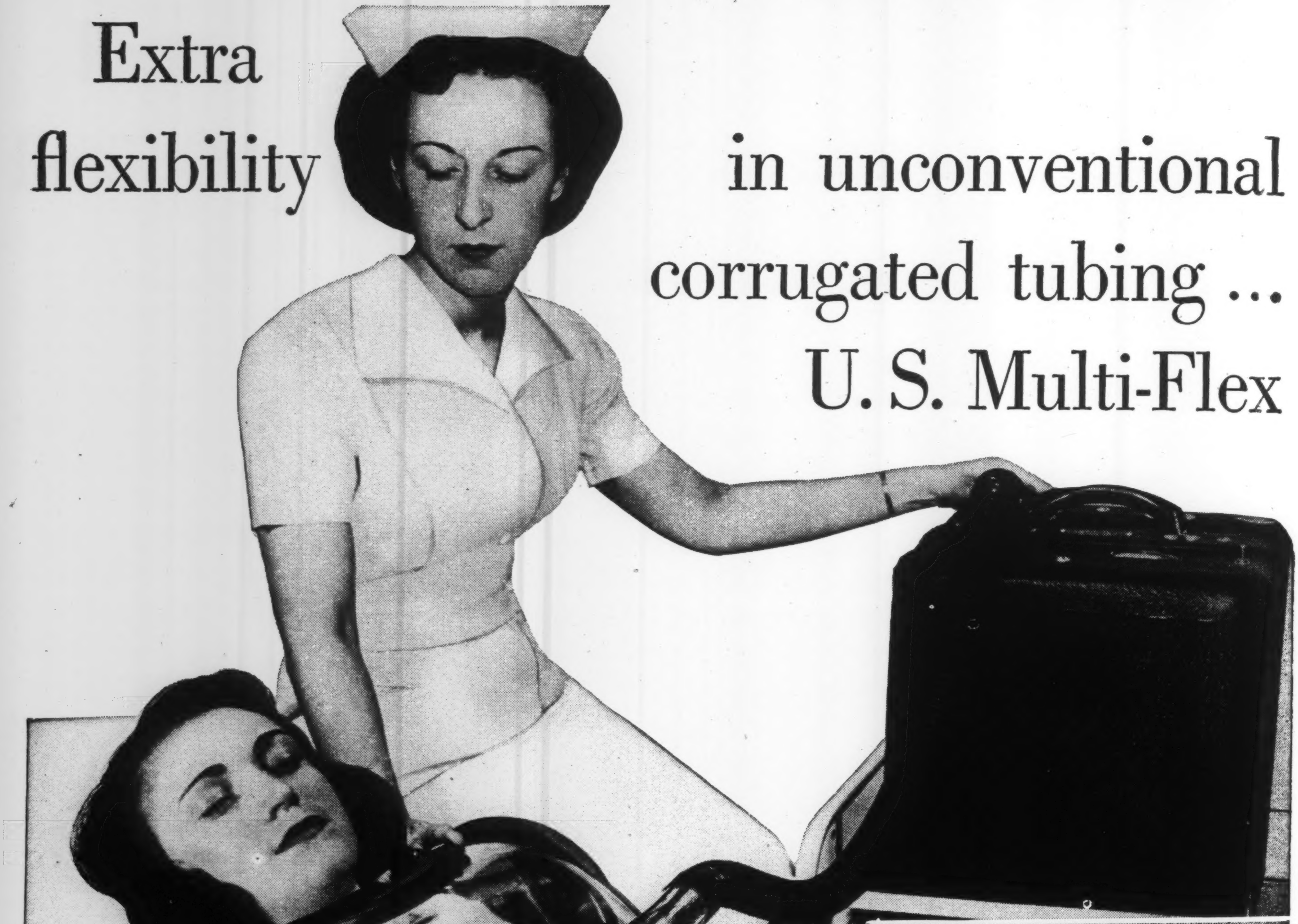


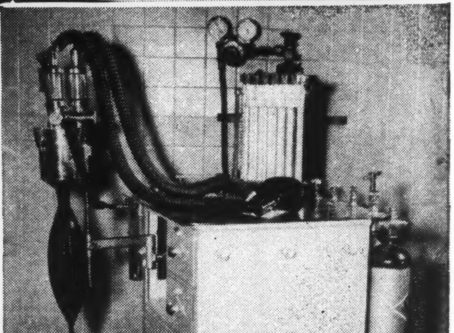
New demands — in industry and in medicine — call for corrugated tubing of extreme flexibility. Equipment designers find U. S. Rubber's unique Multi-Flex® process greatly simplifies their problems.

Multi-Flex means versatility in application. In the medical field, for instance, Multi-Flex corrugated tubes combine *extra flexibility* with *lightness* for anesthesia equipment, and chest respirators. They are resistant to crushing, are non-kinking. When made of conductive rubber, they prevent build-up of static charges.

Multi-Flex products have many small corrugations, yet are made without molds, specially tooled mandrels or inner supporting wires. They are available in any length in diameters from ¼" up. These tubes are made of all rubber, both natural and synthetic, or in combination with various fabrics.

Taking advantage of Multi-Flex Tubing's extreme extensibility, many manufacturers have adopted it for use as a hose on vacuum cleaners, rug shampoo equipment, industrial gas masks and many other products. Multi-Flex Excluder Boots, Air Ducts, Flexible Connectors and Bellows are in wide use throughout industry.

Any designer will do well to investigate the potentialities of this new, unique and economical process. For engineering advice and assistance, call on any of our 27 District Sales Offices, *or* write to address below for a copy of our Multi-Flex Catalog.



Note flexibility of Multi-Flex Tubing on chest respirator (top photo) and (lower photo) on anesthesia equipment.

"U. S." Research perfects it . . . "U. S." Production builds it . . . U. S. Industry depends on it.

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19,000 engineers were graduated, according to previously published reports.

Correction . . .

Gremlins got into our big box of type last month and came up with something that really made our faces red! The die-casting machine photo on this page appeared last month, but with a caption describing something else. We're running it again, this time with the right caption. Look on Page 16 for the photo that was supposed to appear with the caption we printed last month.

Midget Monitor To Guard Engines

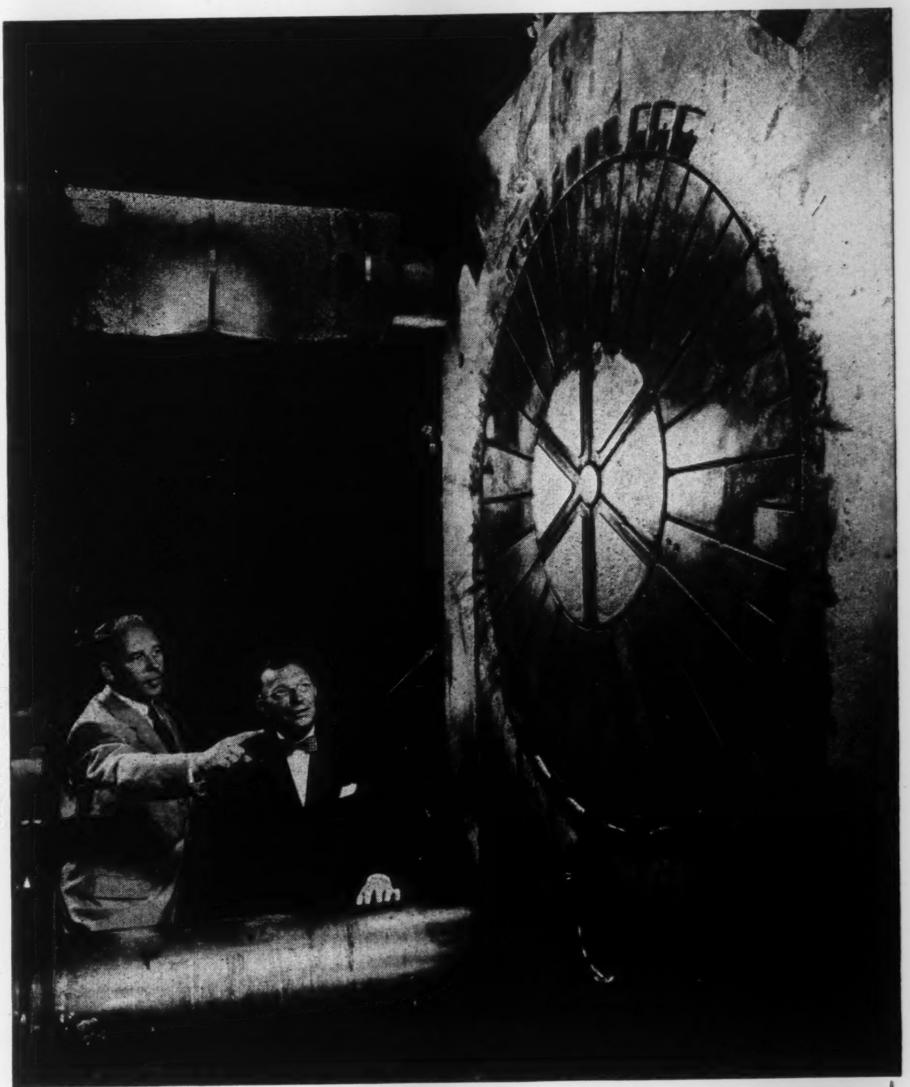
Demonstrating miniature design possibilities using transistors, a recently developed compact monitor system will watch for hot bearings in Naval engines. Designed by Minneapolis-Honeywell Regulator Co. for the U.S. Navy, the system uses transitors to replace vacuum tubes.

By using transistors instead of vacuum tubes, the unit is reduced to one-third the size. Power consumption of the transistorized system is reported to be about one-tenth that of a comparable vacuum tube unit. Weight has also been reduced to about one-tenth.

Thermistors are being used as temperature - sensing elements. They are imbedded in bearings at 40 key points in the engine. By substituting thermistors for thermocouples as sensing elements, much auxiliary equipment was eliminated.

Monitoring of these key points is on a 24-hour basis. Conventional systems scan these points only intermittently. With the new system, a hot bearing causes an alarm to be sounded, and an indicator gives the operator a temperature reading. Thus, faults occurring during operation will be detected before the engine is severely damaged.

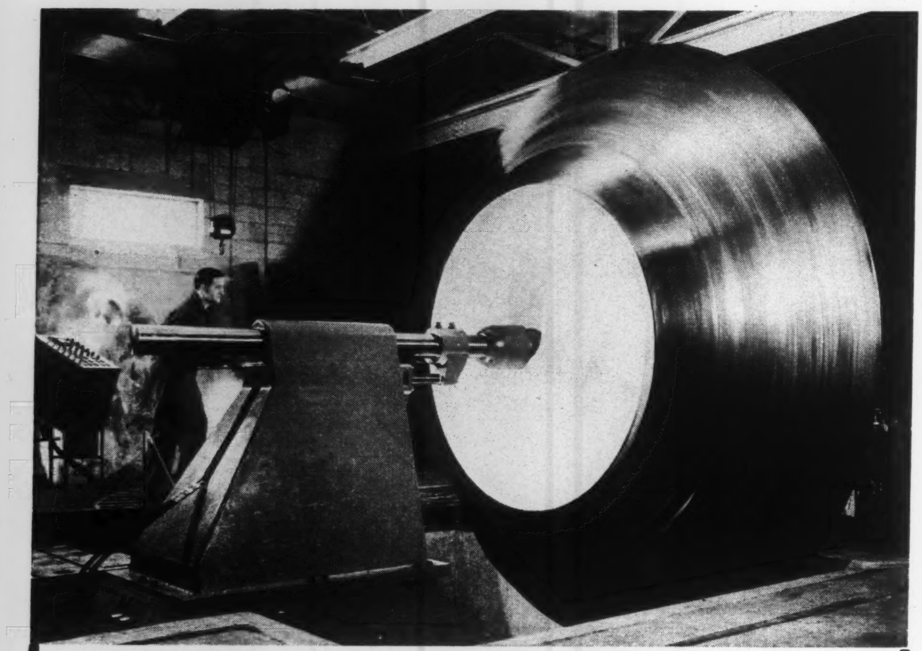
Unusual strain put on marine engines during battle conditions necessitated the development of the new monitor system. It is said to be applicable to most surface and undersea craft.



GIANT DIE CASTING MACHINE, capable of turning out aluminum die castings weighing up to 75 pounds was recently unveiled by Doehler-Jarvis Div. of National Lead Co. in Toledo. Called a "72-inch machine" (distance between centers of four large bars which are the essential framework of a die casting machine) it will handle dies weighing up to 50 tons. It has a maximum die opening of 36 inches and an injection pressure of metal of 6,200 psi

New Order Index of industrial supplies and machinery rose sharply in August after hitting a low for the year the previous month. The American Supply and Machinery Manufacturers' Association reports the new order index for August at 132.5. The July figure was 119.4.

The index measures the flow of orders received by Association members, who are manufacturers of production, operating and maintenance supplies selling to industry through industrial supply distributors. The value of orders received during August was more than 10 per cent above July and almost 33 per cent above the base month of July, 1948.



GIANT SPINNING LATHE spins a 14-foot dome for air-conditioning equipment. Said to be the worlds largest, it can spin shapes up to 180 inches. Hydraulically controlled, it was built by Pheonix Products Co. of Milwaukee and is powered with a 50-hp motor. Speed, clutches, brakes, and all movements of the tail stock are controlled from a portable control panel. Aluminum up to 3/4-inch thick may be spun to a depth of 72 inches

Electronic Brain Takes Over Routine Design Work

Answers to preliminary designs of transformers are turned out in a hurry by a new computer. Reported to free engineers from much routine work, this calculator is being used by General Electric at their Pittsfield plant.

Alternative design data is fed into this IBM machine by punched cards. In less than an hour, GE reports, the machine comes up with preliminary answers, saving up to 40 hours of manual calculation. Preliminary designs are used as a basis for specifications to answer inquiries from prospective purchasers.

Core and coil-design problems, and hot-spot temperature problems, are among the calculations turned out. Because of high operating speed, designers are able to handle a greater number of designs. Education of engineers is also expected to be speeded up as a result.

Saving engineers from routine work will allow them more time for developmental work. Company officials regard this saving as important because of the shortage of engineers.

In the future, the calculator is expected to turn out answers to complex requisition designs. These designs are used by draftsmen in preparing final requisition drawings. Here, a time saving of weeks is expected to be realized.

New research building costing $100,000 is to be built by Consolidated Vultee Aircraft Corp. in San Diego. To be used for electronic computing, the two-story building will be filled with the latest IBM machines and will have air-conditioning and soundproof walls and ceilings.

Previews

Don't Blow a Gasket

There's an art to applying gaskets—both in selecting the right material and in design of an adequate joint. But if you don't want to blow a gasket over gaskets, we'd suggest reading the article on Page 157. Besides giving a very clear idea of the requirements a gasket must meet, the article contains a lot of very helpful information on nonmetallic materials and joint design.

Ideas for the Asking

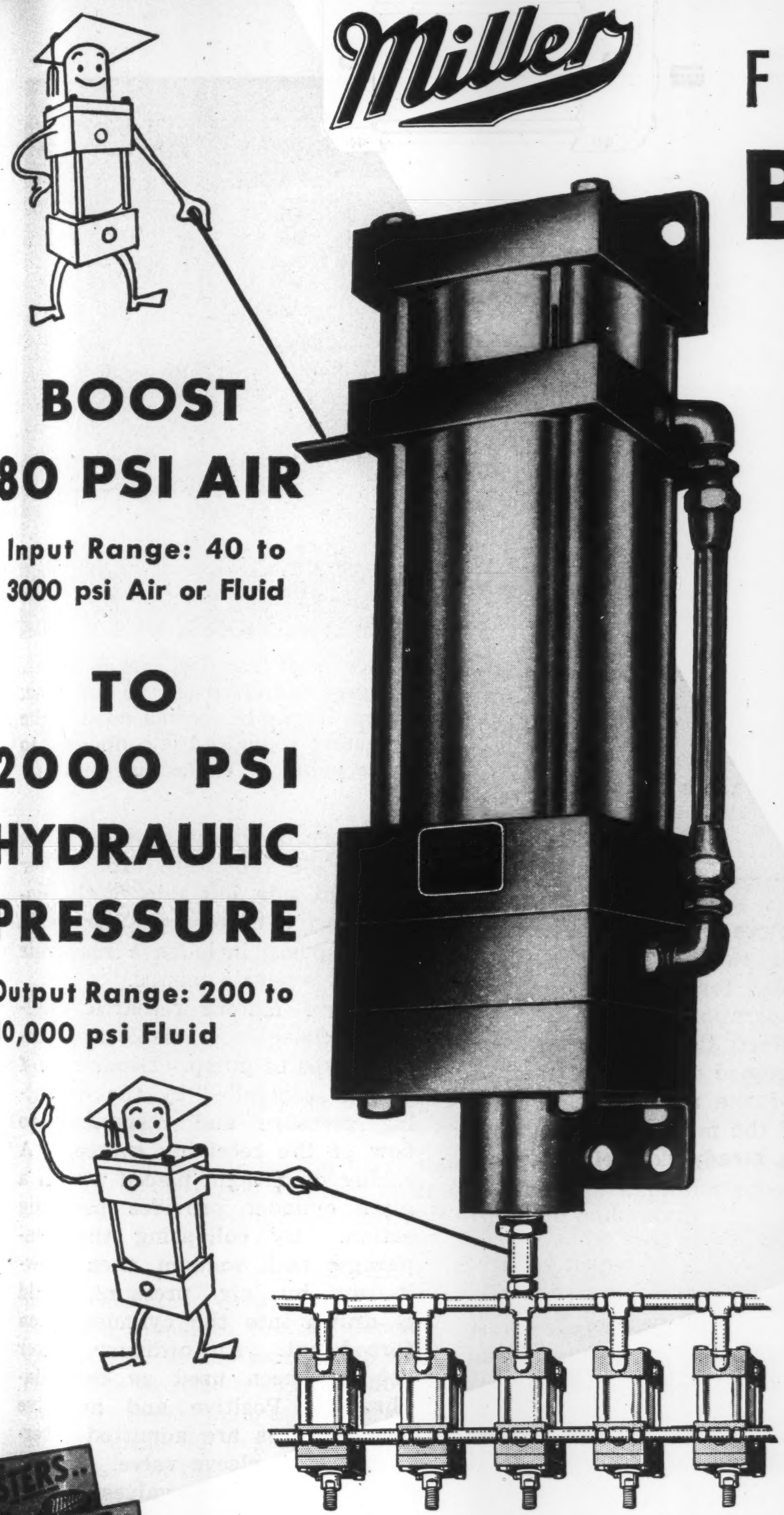
Creative ability can be developed: the spark of inventive genius isn't restricted to a few favored individuals. But creativeness requires exercise and cultivation of a "method," just like any other talent. E. G. Reed, on Page 142, has a fistfull of very pertinent ideas. The article is unusual and, we feel, worthwhile for any designer.

Overweight?

Use of high-strength steel (or other high-strength material, for that matter) is an effective way of reducing weight. One of the important first steps is to get accurate strength data. A simple statistical method is outlined on Page 208. While the article won't make you an accomplished statistician, it does give a practical approach to the problem.

Miller

FLUID PRESSURE BOOSTERS



BOOST 80 PSI AIR

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Output Range: 200 to 10,000 psi Fluid

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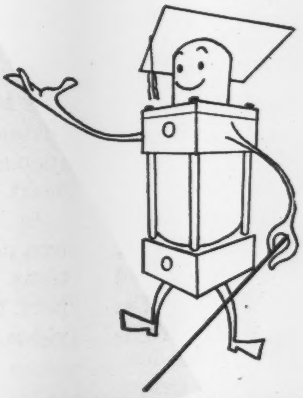
- Operate at speeds of 30 to 450 strokes per minute

NOTE: In addition to its most complete line of "Custom-Built" Boosters available on normal delivery, Miller offers 5" bore, 25 to 1 ratio, boosters ***for immediate delivery*** *in either 6" or 12" stroke. Write for data and prices.*



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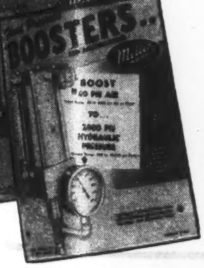

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COUNTERBALANCE CYLINDERS

ROUNDUP FEATURE REPORT

Design Requirements Tops for Medical Equipment

Some recent developments in the medical equipment field emphasize the tight requirements that must be met by design engineers.

Dependability is of the utmost importance. Simplicity of design with few moving parts results in dependable operation as well as minimizing down-time due to maintenance.

Compactness is necessary since operating-room space is at a premium in most cases.

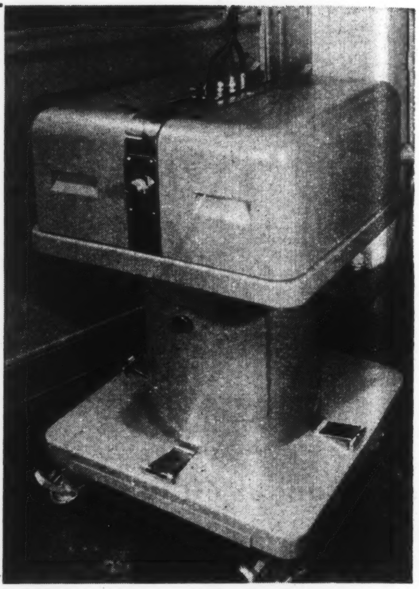
Sterilization of parts must be possible where necessary. Units must be easy to disassemble and materials must withstand high temperatures.

Ease of operation by nontechnical people is a must. An engineer should not be a necessary part of operating-room personnel.

Explosionproof equipment is required in operating rooms because of presence of explosive anesthetic gases.

Patient comfort should be considered.

Co-operation between engineers and doctors has resulted in these recent advances in medical equipment:



Power unit supplies vacuum, air pressure and electricity to the heart pump. It may be located outside the operating room and is connected to the pump by cables and tubing

Mechanical Heart

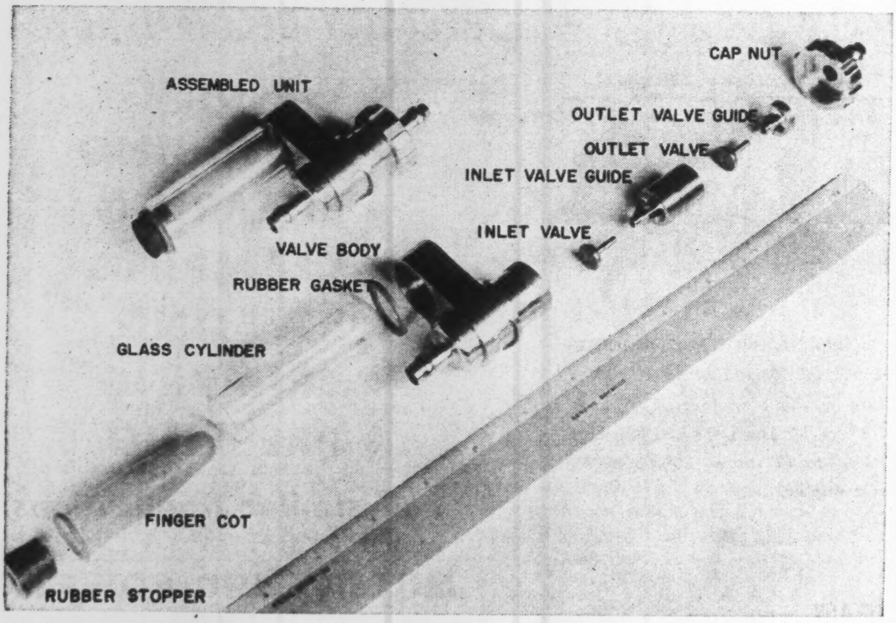
A new pump, designed as a substitute for a human heart, takes over the heart's functions during delicate operations. Developed through the joint efforts of Dr. F. D. Dodrill of Detroit and General Motors Research Laboratories Division, the unit is already responsible for many successful heart operations.

In effect, the mechanical heart was designed to simulate the functions of the natural heart. One part of the mechanical heart provides a steady flow of blood and the other provides the pulsations. It may be substituted for either the right side, left side, or the entire heart if necessary. Each side of the pump includes a reservoir and six separate pumps.

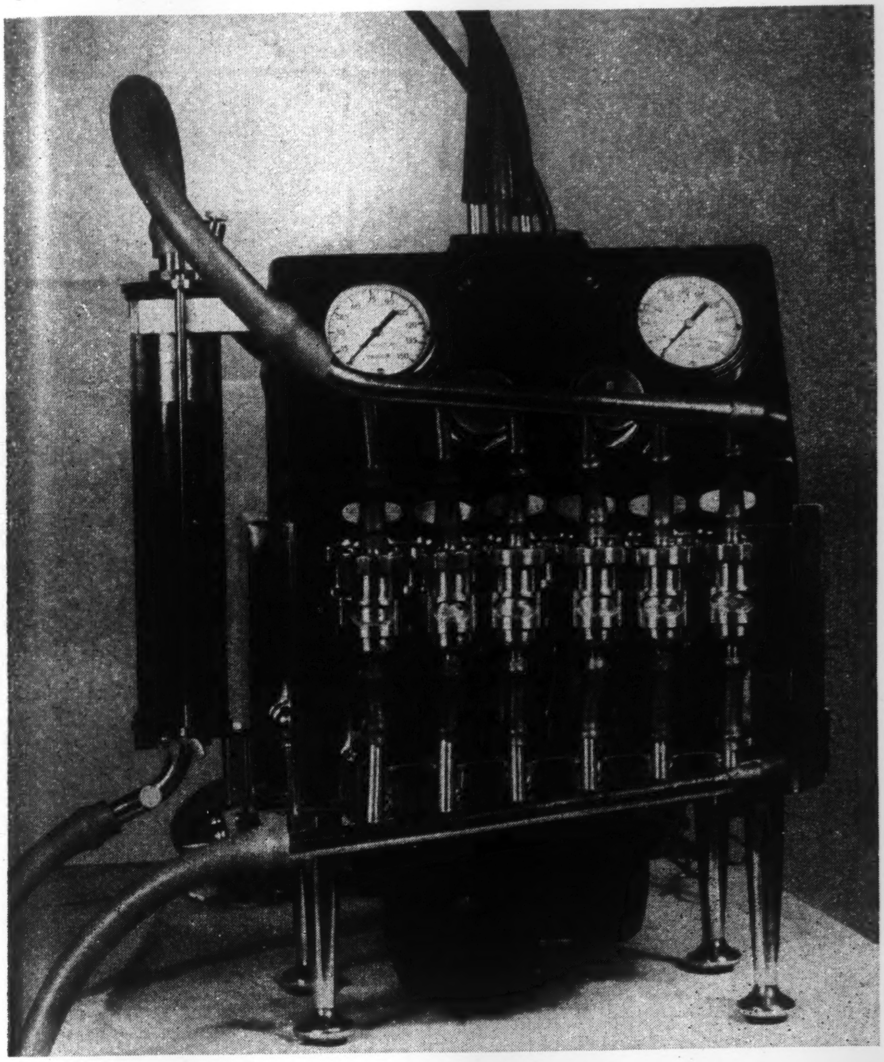
General Motors research engineers chose a variable-displacement type of pump. Discharge of fluid is controlled by the actuating pressure and resistance to flow of the receiving system. A rubber diaphragm placed within a glass cylinder provides pumping action. By collapsing the diaphragm with vacuum, then blow-it up by air pressure, fluid is drawn into the cylinder, then forced out. An ordinary finger cot has been used as the diaphragm. Positive and negative air pressures are admitted alternately by a sleeve valve.

Inlet and outlet valves of the pump provide unidirectional flow. One of the important considerations was to design the valves to close gently so as not to crush the red cells. One layer of cells remains between the valve and its valve seat.

Six individual pumps operate in parallel on each side of the pump. Positive and negative air pressures are valved to all of the pumps by means of a common camshaft driven by an explosion-



Assembly of one of the twelve pumps used in the mechanical heart. Dependability is achieved by simple design with the least number of moving parts



One side of the mechanical heart showing six of the pumps. Vacuum and air lines from the power unit enter from the top. Explosion-proof motor driving the camshaft is suspended underneath

proof motor. Vacuum and air pressure cycled to the six pumps on one side of the machine is arranged to provide a constant flow. One of these pumps discharges during each 60 degrees of cam rotation. On the other side, all of the six pumps are cycled to discharge within 60 degrees of camshaft rotation. Thus, pulsating pressure is supplied to the system. Body capacity of the patient determines the number of units to be used. A step pulley arrangement of the drive permits a choice of camshaft speeds. Separate air and vacuum controls for each side add to the flexibility of the system. Pumping capacity of the machine is reported to be over 5 liters per minute.

Stainless steel has been used wherever possible to reduce wear and breakage and to avoid blood contamination. Finger cots are made of surgical latex rubber and all transparent parts are of Pyrex glass. Sterilization by means of an autoclave, reported to be the most effective sterilization method, may be used because of the heat-resistant qualities of these materials.

All of the surfaces coming in contact with the blood are treated with a silicone compound, making them unwettable. This treatment is believed to help avoid blood clotting within the pump.

Blood flow rate and removal of any air bubbles entering the system are all accomplished in a weir-type flow meter arrangement. Level of blood discharging through a calibrated vertical slot is a function of the flow rate. An air-bleed valve controls the amount of air trapped in the meter while a built-in filter serves to remove unwanted particles in the system.

Power for the machine, as well as air and vacuum, comes from a separate unit. Ordinarily located outside the operating room, the power unit is connected to the heart pump by rubber hoses and an electrical cable. Two air pumps supply pressure and vacuum. Only electric power need be supplied to the machine, thus making it usable wherever electric power can be obtained. While the power unit is relatively large, the heart pump itself measures about 9 by 12 by 14 inches high.

General Motors engineers report that development work is still continuing on the pump. Even though successful, the machine is still considered experimental.

NBS Physiological Monitor

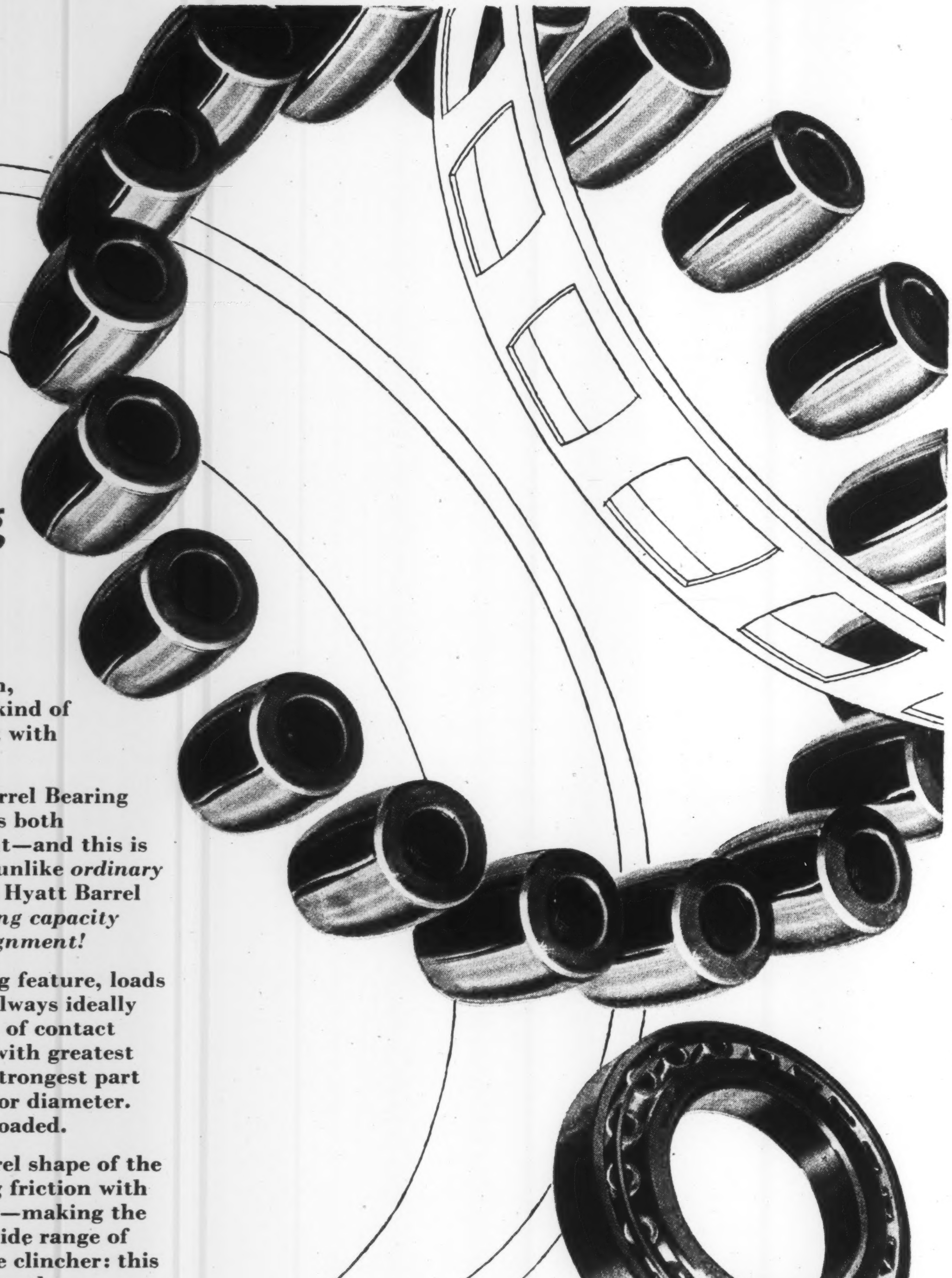
Combining a series of electronic instruments into an integrated group has resulted in a new useful aid to the surgeon. Recently developed by the National Bureau of Standards, the instrument displays a continuous indication on a group of meters of a patient's condition during surgery.

Data on blood pressure, pulse rate, pulse irregularity, breathing rate and amount of air breathed out per minute are available at a glance. No particular technical skill is required on the part of the operator.

All of the electronic assemblies are of the "plug-in" type and are easily replaceable. Safeguards are provided to permit the instrument's use in highly combustible mixtures of anesthetic gases usually present in the operating room.

Two units comprise the system. One is the operating room console consisting of the display of meters. This unit also contains the controls necessary to put the instru-

The barrel does the bearing job better



In the fight against friction, engineers are using a new kind of bearing . . . a bearing built with barrel-shaped rollers.

Developed by Hyatt, the Barrel Bearing is "dual-purpose"—it takes both radial and thrust loads. But—and this is the important difference—unlike *ordinary* dual-purpose bearings, the Hyatt Barrel *operates at full load-carrying capacity under conditions of misalignment!*

Because of this self-aligning feature, loads on the Barrel Bearing are always ideally distributed over large areas of contact between races and rollers, with greatest load concentration at the strongest part of the rollers—at their major diameter. Roller ends cannot be overloaded.

But that's not all. The barrel shape of the rollers combines low rolling friction with high load-carrying capacity—making the Barrel Bearing ideal for a wide range of applications. And here's the clincher: this superior bearing is far less costly than you'd expect—thanks to a new manufacturing process used only by Hyatt.

Does that cover it? You might think so, but it doesn't. There isn't enough space on this page to tell you everything about this new bearing. For full information, write to the address below.

HYATT ROLLER BEARINGS

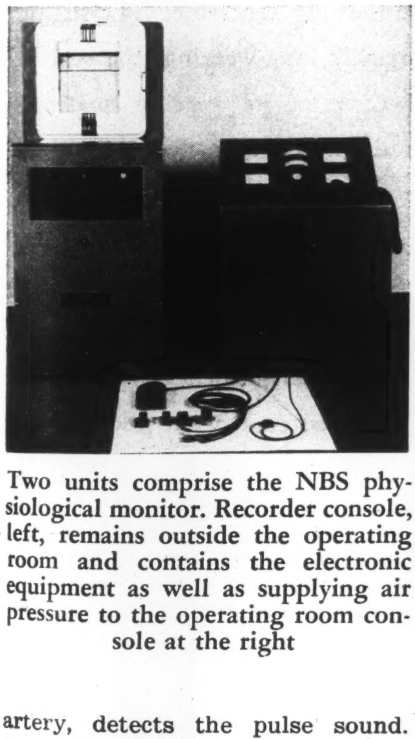
STRAIGHT BARREL TAPER

HYATT BEARINGS DIVISION • GENERAL MOTORS CORPORATION • HARRISON, N. J.

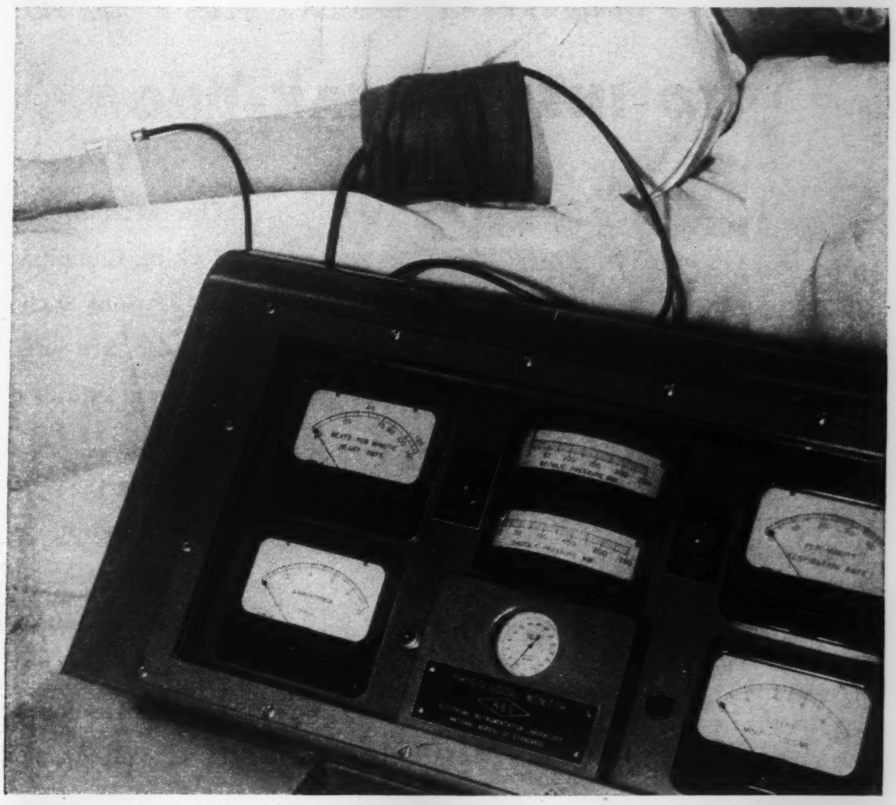
ment into operation.

The other unit, a recorder console, is designed to be placed outside the operating room. It provides a permanent chart record of measurements indicated on the operating room console. An air supply provides air pressure for blood-pressure measurements and for pressurizing the operating room unit to keep it free of explosive vapors. A combination air hose and electric line connects the two units.

Blood-pressure measurements are under the control of a program switch in conjunction with a series of relays and air valves. Every three minutes the valve of an air supply opens and inflates the band around the patient's arm. A microphone, located over the brachial artery, detects the pulse sound. Systolic pressure, associated with the heart's contraction, and diastolic pressure, associated with the heart's expansion, are determined by certain characteristic pulse sounds. By means of amplifiers and relays, the pulses picked up by the microphone actuate two solenoid valves in the air system. These valves are opened to connect the system to the proper pressure indicating gages at the diastolic and systolic points. "Coincidence" circuits reject all pulses that do not coincide with the necessary pressure pulses.



Two units comprise the NBS physiological monitor. Recorder console, left, remains outside the operating room and contains the electronic equipment as well as supplying air pressure to the operating room console at the right



Instrument panel of the NBS physiological monitor. All of the important body functions can be determined by a glance at the meters. Air pressure within the unit is maintained at about ½-lb to keep out explosive gases. From the meter indications, it appears that this patient, obviously, is dead

Pulse rate is taken as a function of the minute voltage changes produced in the body that occur with each heart beat. Time between these adjacent electrical pulses is continuously measured and converted to rate on a calibrated meter. Thus, instantaneous heart rate is measured rather than average rate.

Cardiac irregularity, that is, changes in rate and irregular heart beats, is monitored as a function of an electrical charge on a "memory" capacitor. During time intervals between beats, enough current is supplied the capacitor to keep its charge at a predetermined level. Should there be considerable discrepancy between beats, the level of the electrical charge will change. The resulting current flow is translated into a meter reading.

Respiration-measuring equipment consists of a positive-displacement flowmeter. Rotation of the flowmeter output shaft is proportional to the volume of patient's breath that has passed through the meter. Volume of flow per minute is determined by using a synchrogenerator and a synchromotor. An automatic clutch couples the flowmeter shaft to the sychrogenerator for intervals of 60 seconds. At the end of this time, motor picks up the angular position of the generator and translates that position into a voltage suitable for meter indication. The generator returns to its starting point after each measurement interval.

Size and weight have been held to a minimum. Floor space occupied by the operating room console is only 22 by 26 inches.

Continuous measurements have been made on patients for periods as long as 21 hours. NBS reports that patients can eat, sleep and carry on other activities of bed patients. Accuracy of the machine is reported to compare favorably with the usual methods of measurement.

CRANE PACKING COMPANY'S MECHANICAL SEALS

TO INSURE LEAK-PROOF, TROUBLE-PROOF,

GRAPHITAR ring for type 19 Crane Packing Company Mechanical Shaft Seal

GRAPHITAR ring for type 9 Crane Packing Company Mechanical Shaft Seal

The mechanical shaft seals, manufactured by Crane Packing Company of Chicago, for use on rotating-shaft applications such as centrifugal pumps, turbines and agitators, are designed to handle a wide variety of highly corrosive liquids or gases at temperatures ranging from —100° to 485° F. and pressures up to 750 psi. GRAPHITAR rings, rotating with the shaft and mating against a stationary seat, provide a tight, leak-proof seal with minimum running friction. A free-sliding spring device holds the GRAPHITAR ring in place and automatically compensates for wear on the ring. And since GRAPHITAR is self-lapping and extremely long-wearing, the seal is virtually permanent. Because of its wearing qualities and because it is chemically inert and unaffected by high pressures or temperature extremes, GRAPHITAR proves itself to be by far the most successful material in applications like these.

GRAPHITAR is a versatile engineering material produced from carbon-graphite powders, compacted under high pressures and fused at temperatures exceeding 2000° F. It can be formed in relatively complicated shapes and ground to tolerances as close as .005″ for seals, bearings, valves, piston liners and many other parts. It is lighter than magnesium, harder than most steels and mechanically strong and durable. GRAPHITAR is self-lubricating and can be operated under relatively heavy loads at high temperatures without oil or with a light lubricant such as kerosene or water.

OUR 100th YEAR

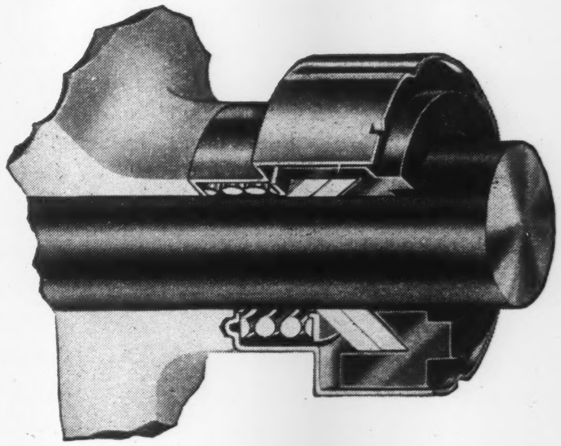
THE UNITED STATES

EMPLOY GRAPHITAR® RINGS

FRICTION-LESS PERFORMANCE

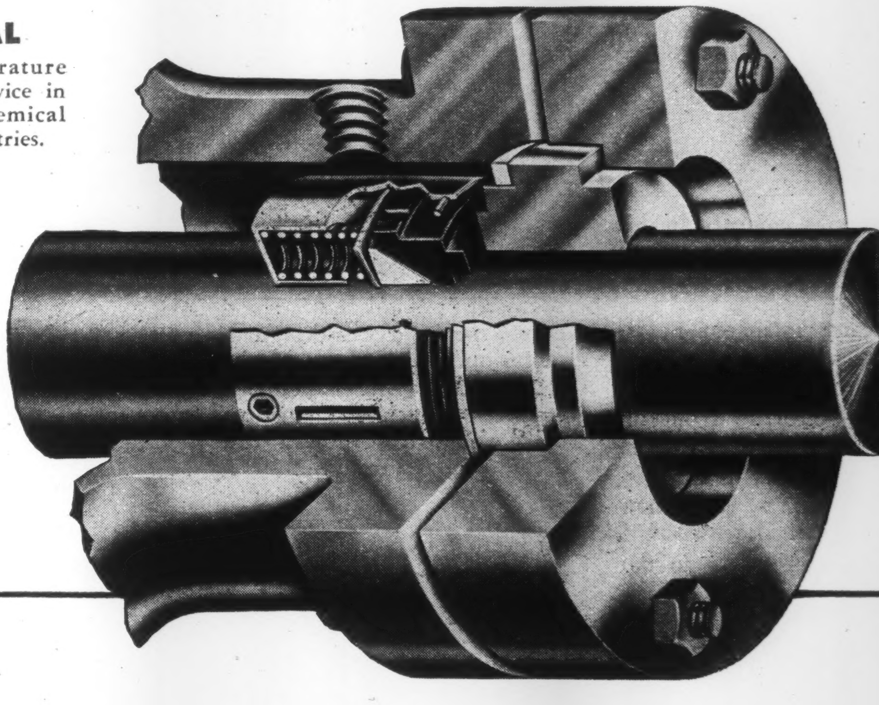
CRANE TYPE 19 SEAL

High production seal for corrosive service on shaft sizes up to ¾ inch.



CRANE TYPE 9 SEAL

For high temperature and corrosive service in chemical, petrochemical and refining industries.



GRAPHITAR parts such as these have become practically indispensable to modern industry. In hundreds of difficult applications, GRAPHITAR is the only successful material for the job. Write for our free 64-page catalog describing many of these applications and including complete information about ways that GRAPHITAR can be used to advantage in your products.

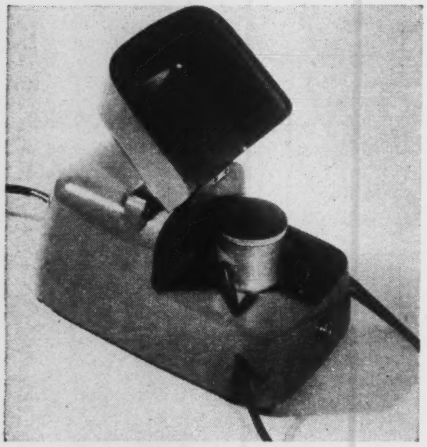
GRAPHITE COMPANY

DIVISION OF THE WICKES CORPORATION, SAGINAW, MICHIGAN

Food Pump

Another co-operative venture between medicine and engineering has resulted in a food pump for feeding and maintaining post-surgical patients and ulcer sufferers.

Conceived by Dr. James Barron of Detroit, the pump was engineered and built for him by the Engineering Div. of Chrysler Corp. One of the problems facing surgeons, according to Dr. Barron, is that of providing sufficient nutrition and high-calorie food to patients who cannot eat after surgery. Patients suffering from ulcers, patients in a coma or even those who aren't hungry for any reason can be fed by this new method.



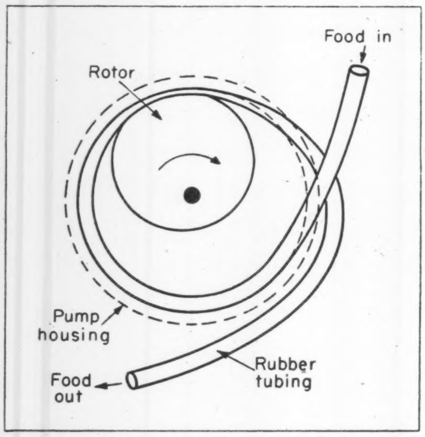
Entire food pump is mounted in this small plastic case for easy handling

Secret of the method is to put a tube down the patient's throat, through his stomach, and pump liquefied food directly into the digestive tract. Although much experimenting was done previous to the development of the Chrysler pump, difficulty was experienced with clogging of tubes and discomfort due to poor control of feeding rate.

Mechanical and design problems involved were licked with the development of a small, rugged, very slow speed pump that operates without touching the food. A specially-designed pear-shaped low-horsepower electric motor powers the pump. Driven through a set of built-in reduction gears, the pump operates at a normal speed of 4½ rpm. The motor measures 3½ inches wide by 3½ inches long.

Feeding rate can be varied to fit the needs of the patient. It can be operated so as to take as long as 10 hours to feed a quart of liquefied food.

Heart of the pump is a replaceable rubber tube mounted in the circular pump housing. Pumping action is produced by an eccentrically mounted rotor that successively compresses the tube as it rotates. The ground-up food is fed into the pump by gravity, squeezed through it by means of the eccentric rotor then piped into the patient. By making the rubber tubing removable, sterilization problems are greatly simplified.



How the Chrysler-designed food pump operates without touching the food is shown. Eccentric rotor squeezes the tube against the side of the pump case, forcing the food through

The system is said to have been proven successful with about 400 patients. Some of these were fed by the new pump for periods up to 79 days.

Harold F. Marsh has been elected president of General Mfg. Co. F. C. Hossies, founder, and designer of Flexible power presses, was elected secretary.

Mechanisms Conference Again Pronounced Success

Over 250 engineers from all parts of the United States attended the Second Mechanisms Conference at Purdue University on October 11 and 12. Cosponsored by Purdue University, MACHINE DESIGN and *Automation,* the conference featured 8 papers dealing with important phases of mechanism design.

The Conference was held to promote better understanding, design and application of mechanisms. Four major sessions covered special gearing, mechanism performance analysis, cam design problems and control mechanisms. In addition to papers presented by top authorities on these subjects, two panel group discussions rounded out the program. Here, there was an exchange of ideas on mechanism synthesis and manufacturing tolerances.

Proceedings of the Conference will be published in the December issue of MACHINE DESIGN. Individual copies will be made available.

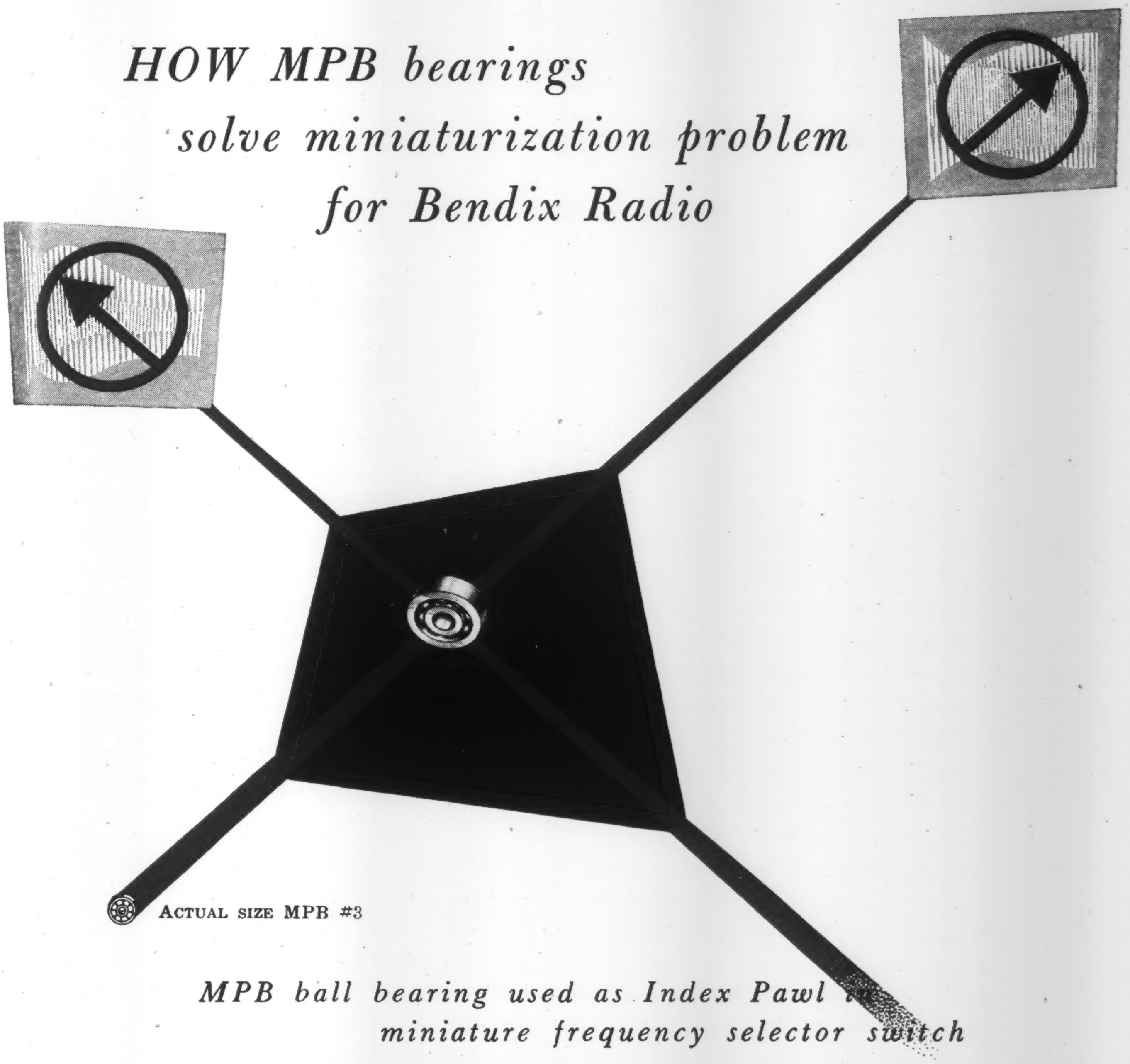
Tubing Drawn Six-Shooter Style

New 85-foot cold draw bench now in operation at the Huntington Works of International Nickel Inc. uses a magazine loading device. Six mandrels in sets of three are placed one above the other in a revolving cylinder. While the tubing is being drawn in the lower part of the cylinder, the upper three are loaded in preparation for the next draw. At the end of the drawing operation, while the "mule" is being returned to the starting position, the cylinder revolves and brings the three mandrels with tubes on them into position before the dies.

Present length limits of Inconel tubes and rods are extended with the operation of the new facility. Rods up to 85 feet in length may be drawn.

Associated with the new draw bench is a 220-foot-long annealing

HOW MPB bearings solve miniaturization problem for Bendix Radio



MPB ball bearing used as Index Pawl in miniature frequency selector switch

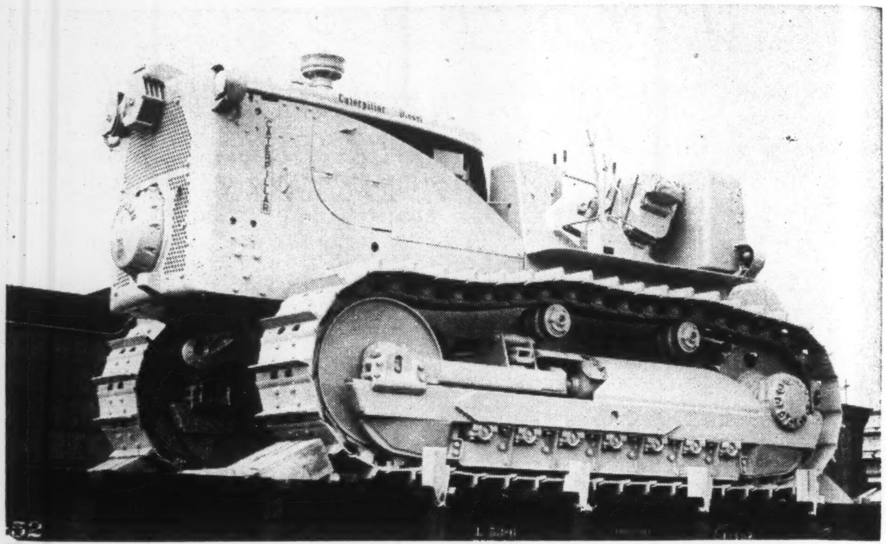
OPERATING CONDITIONS — miniature ball bearing serves as index pawl in 4-position indexing device . . . bearing travels at 936 r.p.m. **CRITICAL** — low starting torque, low friction rotation . . . high impact loads . . . long, trouble-free bearing life. **RESOLVED** — by use of MPB No. 3, .1875″ o.d. full-race bearing.

To quote Mr. John F. Wroten, Jr., mechanical engineer with Bendix Radio Division, these are some of the reasons why MPB bearings were selected in the miniaturization of their frequency selector switch: "The low friction rotation of the bearing practically eliminates drag in the indexing action, and reduces to a minimum the amount of power required for disengagement. Also, the bearing displays unusually high resistance to the frequent impact loads a detent stop of this kind must withstand . . . . Because rolling contact occurs between the pawl and the plate, the plate can be made of soft stainless steel."

For problems involving miniaturization, consult MPB, pioneer manufacturer of miniature ball bearings.

Miniature *Precision* Bearings, Inc., 104 Carpenter St., Keene, N. H.

furnace. Inconel rollers in the furnace are capable of withstanding temperatures up to 2000 F without the use of any cooling agents.



MOST POWERFUL CAT is also said to be the largest crawler tractor in the world. Labelled the D9X by the Caterpillar Tractor Co., the machine is 18 feet long, 12 feet wide and 10 feet high. Bare weight is 51,500 pounds; bulldozer blade and cable control add another 11,000 pounds. In addition to tests at company proving grounds, several of the giants are assigned to actual on-the-job testing on the Ohio Turnpike construction

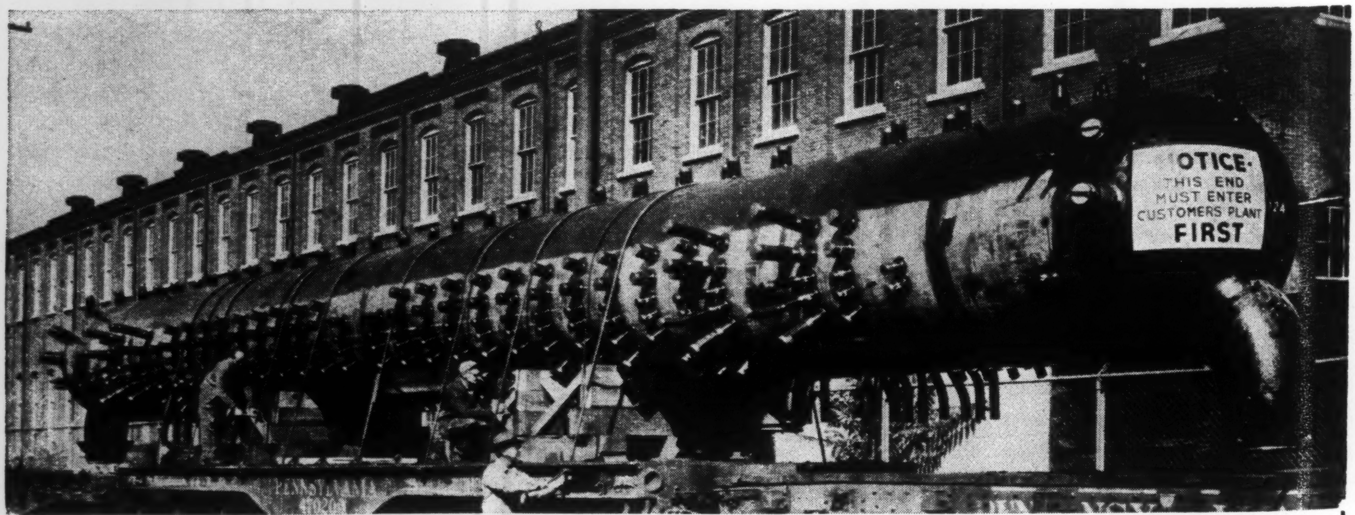
Salary Survey Points Up Industry-Wide Similarities

Type of industry, location or size of companies seem to make no difference in salary levels of technical and administrative employees. These are results of a recent survey made by the American Management Association.

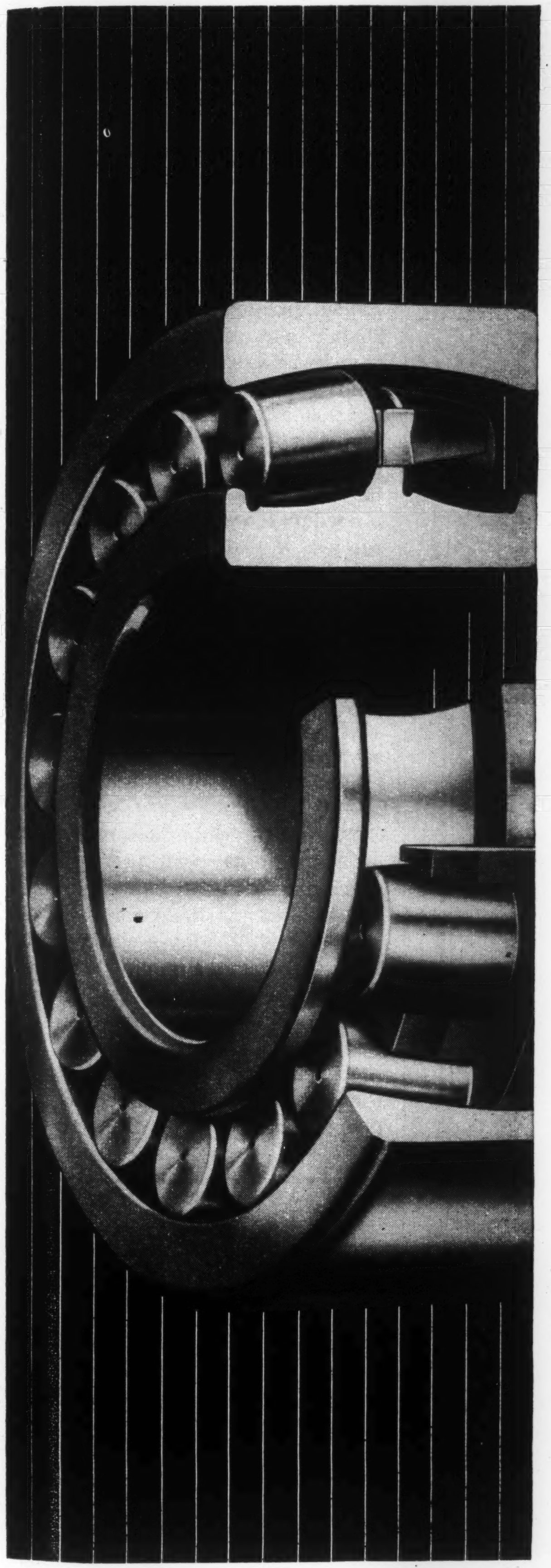
Thirty-two companies in 16 industries covered in the survey were located both in urban and rural areas. Annual sales of the surveyed companies ranged from less than $5 million to more than $500 million and number of employees ranged from less than 1000 to over 30,000.

Average variation between the lowest and highest salaries paid for the 20 positions studied was only 54 per cent. This variation was not much greater than variations found in salary ranges in individual companies for a given position. It was found, for example, that the highest rate paid for a junior engineer is only 26 per cent above the lowest paid rate.

Generally, AMA reports, technical personnel are given the same treatment as middle management in matters of salary administration. Policies on overtime and general salary increases are similar for most employees exempt from compulsory overtime penalty pay



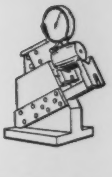
GIANT BAG PIPES? No, these three railroad flat cars are carrying a 193-ton steam drum. Fabricated by Babcock and Wilcox Co., the drum is to become part of the largest single boiler ever to be built, according to company officials. To be 15 stories high, the huge boiler will supply steam to two Detroit Edison turbine generators at a pressure of 2000 psi at a maximum rate of nearly 1¾ million pounds per hour. The welded drum is 82 feet long with 6-inch thick walls



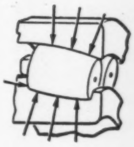
why it pays to specify

TORRINGTON

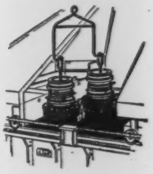
Spherical Roller Bearings



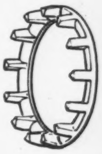
Uniform, close control of precision-ground contact surfaces—for even load distribution and maximum bearing life.



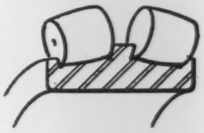
Accurate geometrical conformity between races and rollers—for ultimate load carrying capacity and performance.



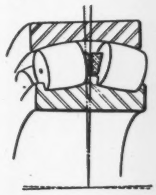
Races and rollers heat treated according to the most advanced metallurgical procedures—for maximum durability.



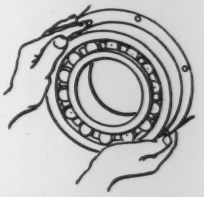
Individual one-piece cage for each path of rollers—assures freedom of operation.



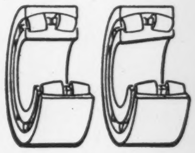
Integral flange on inner race—to give radial stability and positioning for thrust loads—both essential to satisfactory performance.



Self-aligning—for continuous, free-rolling service under shock loads and at sustained speeds.



Unit assembly—for easy, economical handling.



Available from stock with either straight or tapered bore—for shaft or adapter mounting.

These are advantages that give you long, efficient, low-maintenance service in the toughest heavy-duty application.* To get maximum value for your bearing dollar, *specify TORRINGTON Spherical Roller Bearings.

THE TORRINGTON COMPANY
South Bend 21, Ind. • Torrington, Conn.

TORRINGTON SPHERICAL ROLLER BEARINGS

Spherical Roller • Tapered Roller • Cylindrical Roller • Needle • Ball • Needle Rollers

provisions. It was found that 21 per cent of 600 companies surveyed paid exempt personnel additional compensation for overtime work. One-third of these companies do not extend overtime compensation beyond the $7000-a-year pay level.

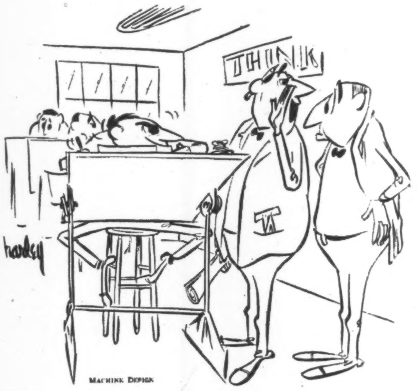
General salary increases are extended to exempt employees by 35 per cent of the companies surveyed, AMA says. Many do not extend general increases above the $10,000 a year salary level. Forty per cent have formal salary programs for exempt technical employees. Most use job evaluation procedures and established salary ranges.

Camera Stays Up All Night to Read Meters

Unique way of taking data to save engineers a few sleepless nights was demonstrated recently by the Wright Air Development Center's Materials Laboratory.

Creep-rupture testing of metals requires reading of time, temperature and stress indicators on a 24 hour-a-day, 7 day-a-week basis. To avoid using engineers for this routine task, a converted movie camera has been adapted to do this job.

Aimed at the dials and gages, the movie camera is timed to take one photograph at a time at pre-



"I've found the best way to make Johnston work hard is to let him think he's designing a machine to replace me."

Fusionweld

IT'S TOUGHER • MORE DUCTILE • SMOOTHER • MORE ECONOMICAL TO FABRICATE

Fusionweld IS TOUGHER . . . Avon's own exclusive high frequency resistance welding method produces an entirely new uniformity of grain structure in the welded and adjacent wall area by means of an advanced type of electronic control. This exclusive process combined with our improved cold drawing of larger size tubing into smaller diameters is responsible for the extremely smooth surface finish, closer diameter tolerances and new ease of fabricating.

Fusionweld HAS A PERFECTED SINGLE WALL CONSTRUCTION . . . Avon is able to offer thin wall tubing as a highly impressive substitute for costlier tubing—both ferrous and non-ferrous—because of its hi-cycle method of controlled welding. This tubing is available in three tempers—"as welded," "as drawn" and annealed to insure the last word in adaptability to varied tubing uses. It is more economically fabricated—takes tougher bends, beads, flares, etc.—withstands pressures up to 18,000 PSI—has no equal in resisting the severest types of fatigue from vibration.

Fusionweld IS EASIER TO FABRICATE . . . Avon's exclusive tube making process has proved itself, matching the most difficult forming operations, with a higher degree of ductility and tensile strength to insure new fabricating ease, lower scrap loss, greater performance reliability. Today our mills are successfully producing over 7½ million feet per month for hundreds of important tubing applications. Our sales engineering staff will gladly assist you . . . or send us your blue prints for tube quotations.

•

3/16" O.D. to 3/4" O.D.
PLAIN OR TERNE COATED

AVON FUSIONWELD Steel Tubing
"The Tubing With a Future"
AVON TUBE DIVISION

AVON TUBE DIVISION
HIGBIE MANUFACTURING CO.
ROCHESTER MICHIGAN

determined intervals. A time switch turns on the lights, trips the shutter and advances the film one frame for the next photograph. Thus, all of the data is continuously recorded by the camera.

In addition to providing errorless recording of data, the device is said to cut by 75 per cent the number of man-hours required for a creep-rupture test.

Human Weaknesses Cause Business Failures

According to a recent "failure study" made by Dun and Bradstreet, most business concerns failing in 1953 had been in business 5 years or less. Underlying causes of these business failures were found to be human weaknesses.

Incompetence or lack of managerial ability took the highest toll in all classes. Manufacturers were hit hardest in this score. Failures of most businesses were due to lack of well-rounded experience in sales, finance, purchasing and production in the part of the management unit. However, these factors are not as important in manufacturing industries. These human failings comprise 89.4 per cent of the total failure causes for all classes surveyed.

Failure Rates in Manufacturing, 1953

Line of Industry	Rate Per 10,000 Concerns
Furniture	186
Leather and shoes	175
Apparel	129
Transportation equipment	118
Electrical machinery	98
Chemicals and drugs	82
Textiles	79
Food	71
Paper	69
Metals, primary and fabricated	68
Machinery	53
Stone, clay and glass	42
Printing and publishing	16
Lumber	13

Highest apparent cause of manufacturers' troubles was inadequate sales, followed by competitive weakness and excessive fixed assets. Receivable difficulties was also listed as a major apparent cause of failures. Such things as fraud, disaster and poor location were inconsequential

S-l-i-d-i-n-g

CONTACTS & BRUSHES OF SILVER-GRAPHITE

. . . for minimum, more stable contact resistance . . . less radio noise interference . . . greater reliability

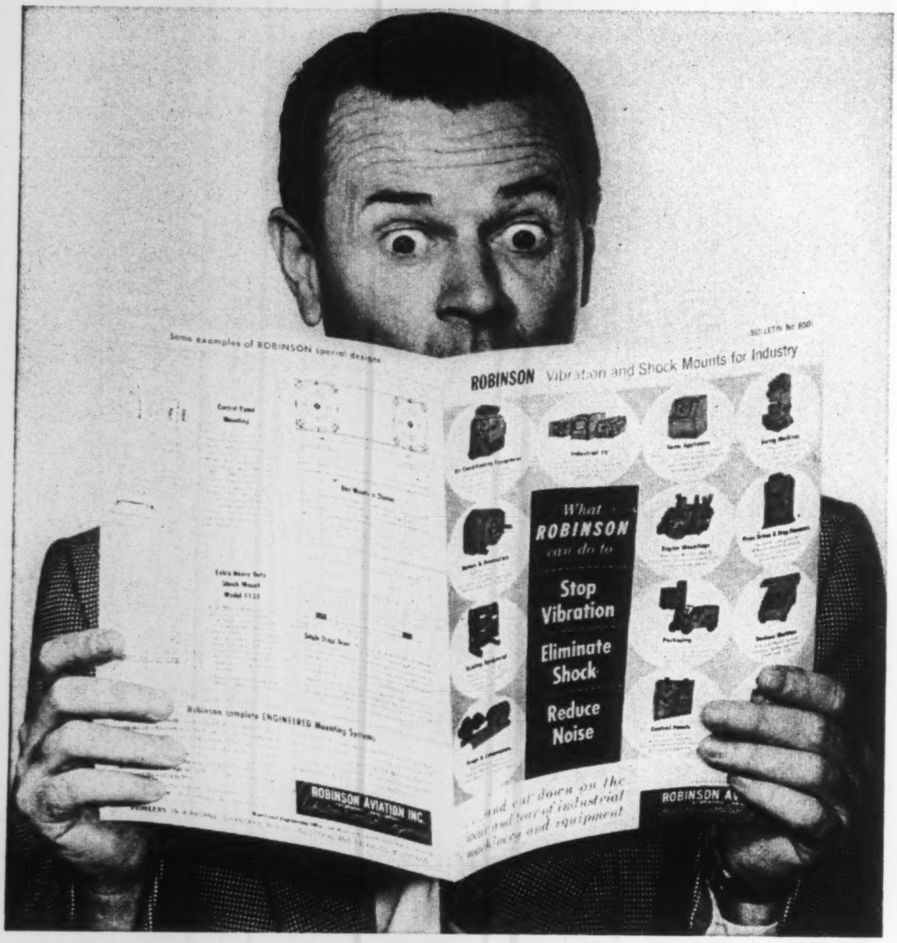
From servo mechanisms to radar antenna operating units, calculating machines, midget motors and dozens of other exacting applications, sliding contacts or brushes of Stackpole silver-graphite assure maximum contact efficiency and life at minimum cost. Lowest radio noise levels short of using costly noble metals are obtained by using these silver-graphite units against a silver ring. For ordinary uses, a copper ring or commutator will suffice.

Available in sizes from 1/16" diameter upward, they can be supplied with silver-soldered backs for easy spot welding or brazing directly to supporting springs or arms and with or without shunts. Contacting assemblies are thus greatly simplified. Units are supplied either separate or mounted to specifications. They are made of silver with almost any desired percentage of graphite. Standard grades range from 0% to 50% graphite.

STACKPOLE CARBON COMPANY
St. Marys, Pa.

STACKPOLE

Stackpole contact material types include: SILVER-GRAPHITE • SILVER-LEAD OXIDE SILVER-NICKEL • SILVER-MOLYBDENUM • SILVER-TUNGSTEN • COPPER-GRAPHITE SILVER-COPPER-GRAPHITE • GOLD-GRAPHITE • SILVER-IRON OXIDE and many special grades.


ROBINSON Vibration and Shock Mounts for Industry
What ROBINSON can do to
Stop Vibration
Eliminate Shock
Reduce Noise
ROBINSON AVIATION INC.

Your eyes will open, too, at this new concept of

VIBRATION and SHOCK CONTROL

First to recognize the advantages of all metal mounting systems, Robinson launched an entirely new concept of vibration and shock control. This new concept offers the answer to many of today's unusual and exacting engineering problems.

Outstanding feature of Robinson systems is the employment of resilient load-carrying cushions of metal wire (Met-L-Flex). These metal cushions are actually knitted so as to form a multiplicity of interlocking springs continuous from top to bottom. The result is that mounted equipment literally floats on a cushion of thousands of tiny springs. Performance is unaffected by grease, oil, water, dust or extreme temperatures. Inherent high damping assures complete control of shock and vibration at all times.

Highest standards of performance proven by years of severe testing in military installations, the Robinson concept is now available in industrial fields.

Send for free booklet

For full information about this new concept of vibration control, whether your problem involves delicate instruments or heavy machinery, send for booklet 850. Write or wire today. Industrial Division Dept. MD3.

ROBINSON AVIATION INC.
TETERBORO, NEW JERSEY
Vibration Control Engineers

among reasons for not making the grade.

Average liabilities per failure in 1953 for manufacturing concerns was $85,543. Average of all the concerns surveyed was $44,477.

Breakup of 1953 failures into nine areas of the United States showed wide variations. Most failures occurred in the Pacific area with a failure rate of 86.9 per 10,000 concerns. California led the parade with 108.9 concerns per 10,000 going out of business. Lowest was the West North Central area with 10.4 failures per 10,000 including South Dakota with a low of 2.3. Failures by area stacked up in the following order: Pacific was highest, followed by Middle Atlantic, New England, Mountain, South Atlantic, East North Central, East South Central, West South Central and West North Central.

Dun and Bradstreet report that on every business day in 1953, an average of 29 businesses went under.

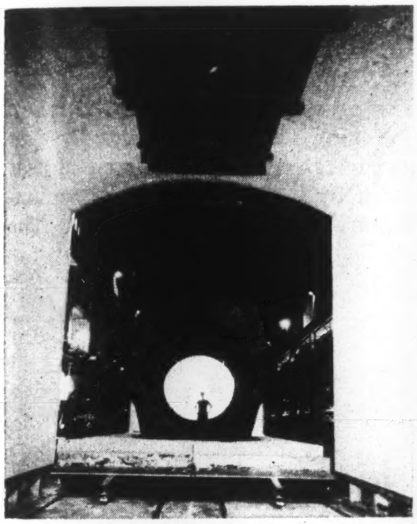
Research Center Studies Accidents

Accident prevention in the industrial field is being studied in a new research center, according to Arthur D. Little Inc. Operated by Liberty Mutual Insurance Co., the laboratory will be concerned mostly with present-day complicated, powerful machinery and complex manufacturing techniques. Emphasis will be on causes underlying industrial casualty reports.

Industrial noise is one of the first problems being attacked. Communications and fatigue are two major considerations in connection with industrial noise. If a machine is so noisy that ordinary conversation is impractical, new workers cannot be properly trained on the job. Redesign of machine parts, acoustic baffles or changes in operating methods may be recommended.

Oxygen consumed by a worker when sitting still or when engaged in an industrial operation is analyzed in another test. Relating this measurement to expended efforts may lead to redesign of machines to reduce operator fatigue.

Research results of the laboratory are published and reports of successful machine modifications are available to industry at large.



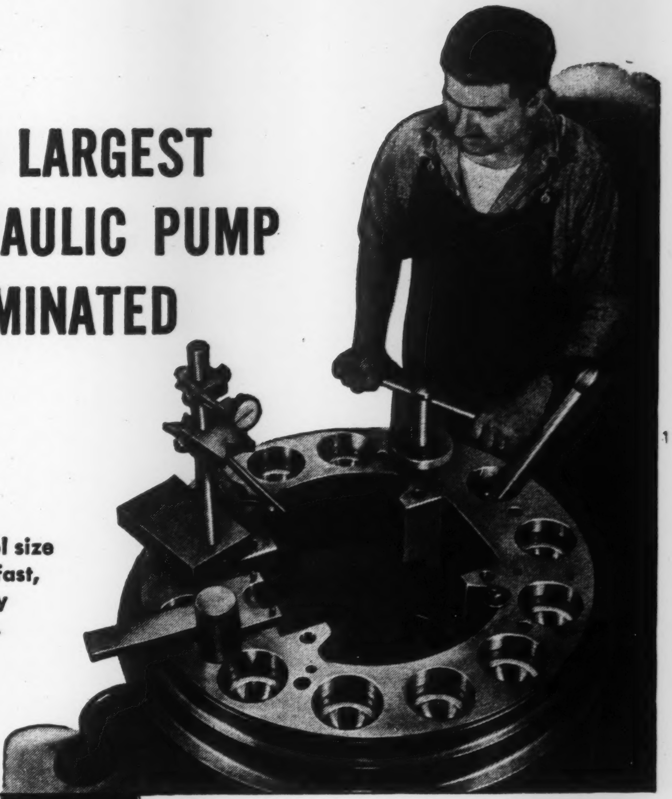
BIG AS A HOUSE is this new Westinghouse car-type gas heat-treating furnace. Reported big enough to contain a modest one-story bungalow, the furnace will be used for stress relieving of large weldments. With a usable charge space 30-feet long, 18-feet wide and 16-feet high, parts weighing up to 100 tons may be treated at one time

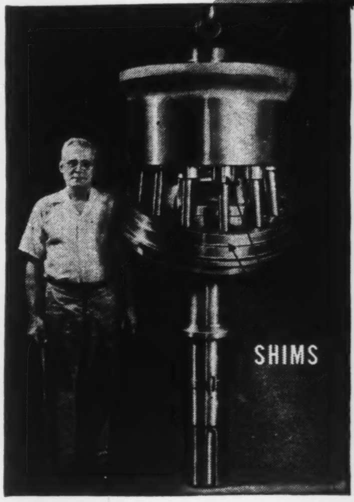
More New Aluminum Designations

Two aluminum alloys have been given designation numbers in accordance with the recently announced aluminum alloy designation system (MACHINE DESIGN, Sept., 1954, Page 30). Said to be the world's strongest aluminum alloy for production use, HZM 100 is now 7001. Developed this year by Harvey Aluminum, the alloy is

WORLD'S LARGEST OIL HYDRAULIC PUMP USES LAMINATED SHIMS

New Waterbury Tool size "300" pumps gain fast, accurate fit and easy service adjustments.





Heart of this huge 20-ton hydraulic pump is the immense revolving assembly of angle plate, connecting rods and pistons. Tilting the angle plate permits rapid reversing under heavy load. Both ends of the connecting rod bearings – at angle plate and pistons – are assembled and adjusted with Laminated Shims. Shown in large picture is angle plate being assembled. Smaller picture gives size of complete revolving assembly. Pumps will be used in Tube Reducing Machine being built by E. W. Bliss Co. for the Tube Reducing Corp.

The largest oil hydraulic high pressure pumps ever built presented a host of new engineering problems—but the old, familiar problems of fast accurate assembly and easy service adjustments were solved by the old familiar remedy . . . *laminated shims!*

For laminated shims in steel, stainless steel, brass, aluminum and combinations of metals call us first! Forty years of shim engineering experience are at your service! Please write for further information and our new catalogue, yours without cost or obligation.

Simply P-E-E-L for adjustment.

SHIM HEADQUARTERS SINCE 1913

Check Our Stampings Division
For Your Stamped Parts Requirements

LAMINATED SHIM COMPANY, INC.

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UNIFORM QUALITY
DIVERSE
APPLICATIONS
CURTIS
the only Universal Joint with the
"Telltale" Lock Ring
(patented)

Each part of every Curtis Universal Joint is made of specially selected steel, individually heat-treated for a specific purpose. This care in manufacture is reflected in our catalog torque and load ratings — which are substantiated by constant testing of production joints.

That's why Curtis Joints are the most dependable, durable and trouble-free available—the standard of the industry.

CURTIS UNIVERSAL JOINTS

- 14 sizes always in stock — bored or unbored hubs
- Fewer parts, simpler construction
- Complete equipment for government tests

PLUS — facilities and engineering skill to handle special specification jobs at any time.

Not sold through distributors. Write direct for free engineering data and price list.

TRADE MARK **CURTIS**
UNIVERSAL JOINT CO., INC.
5 BIRNIE AVENUE, SPRINGFIELD, MASS.

As near to you as your telephone

A MANUFACTURER OF
UNIVERSAL JOINTS SINCE 1919

being used to produce extruded shapes and forgings.

Alloy 7001 has a typical ultimate strength of approximately 100,000 psi. It is designed for high-stress structural applications.

Aluminum alloy 66S has also been added to the new designation list. In accordance with the Aluminum Association's new system, 66S will be labeled 6066.

Harvey Aluminum reports that 6066 combines high strength found in the copper series alloys with economy, ideal weldability and corrosion resistance.

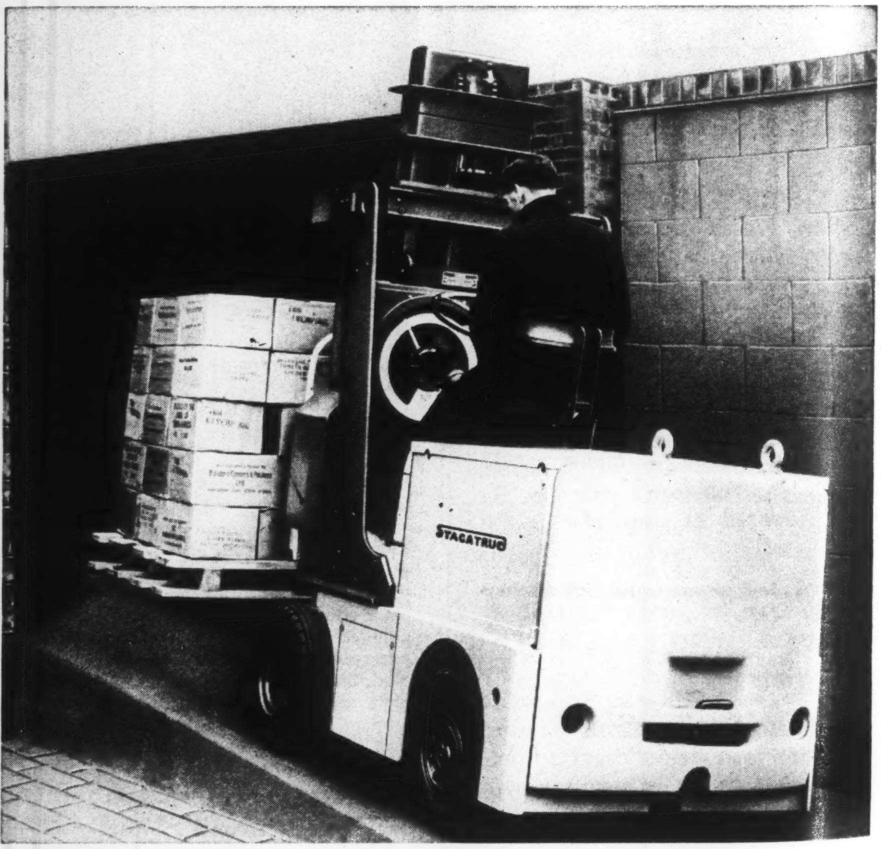
An Industrial Exposition is one of the features of a series of programs planned to celebrate The Michigan State College centennial in 1955. Now the nation's ninth largest university, Michigan State was founded in 1855 as the country's first agricultural college.

Rocket Sets New Altitude Record

Altitude record for single-stage rockets was set recently when the Naval Research Laboratory's Viking 11 reached a height of 158 miles above the White Sands Proving Grounds at Las Cruces, N. M. The previous record was 136 miles.

Viking 11, measuring 45 feet and weighing 7½ tons, topped that mark by 22 miles, reaching a maximum speed of 4300 mph. The

(*Continued on Page* 38)



WEIGH-AS-YOU-GO fork-lift truck pictured here is of British design. By utilizing built in weighing equipment, much manhandling of loads on and off conventional scales is eliminated. Made by I. T. D. Ltd., London, the truck has a capacity of 2000 pounds with automatic locking to protect the weighing mechanism

Where quality

is the first consideration

in the manufacture

of a product . . .

there is no substitute

for the skill and experience

of Holo-Krome's

socket screw experts

Holo-Krome Socket Screws are always fairly priced. Standard catalog items always available right from stock through Holo-Krome authorized industrial distributors

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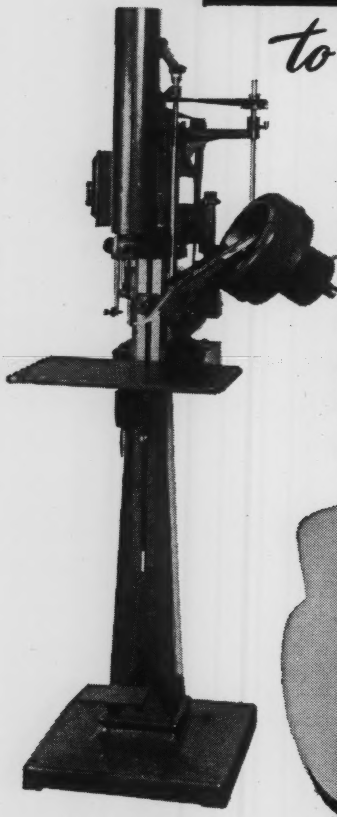
HARTFORD 10, CONNECTICUT, U.S.A.

LET US ADAPT—

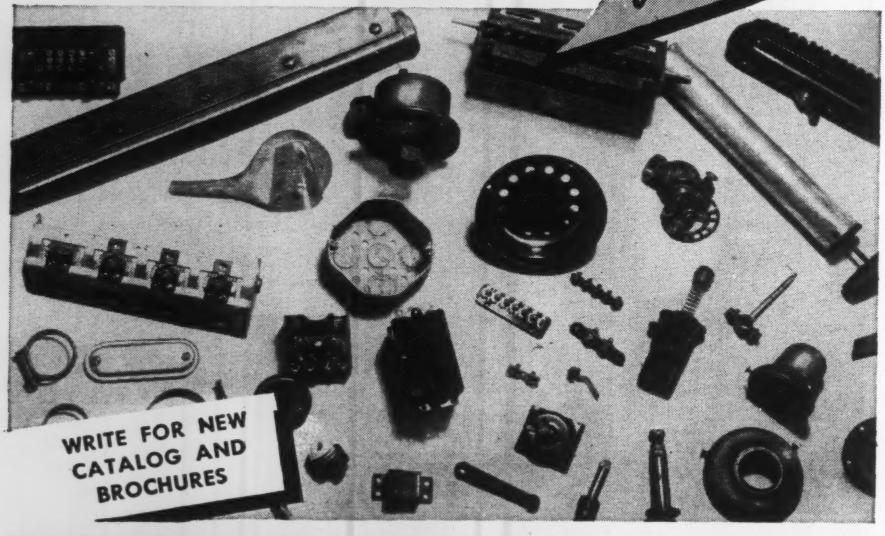
DPS MODERN ASSEMBLING EQUIPMENT

to Your Individual Needs



DPS POWER SCREWDRIVERS and SELECTIVE PARTS FEEDERS will give you outstanding performance: greatly stepped-up assembly speed, lower costs, accuracy and uniform results.

Below—a very small portion of the more than 10,000 Applications we have done for others. We can do the same for You!



WRITE FOR NEW CATALOG AND BROCHURES

DETROIT POWER SCREWDRIVER CO.

2801-A W. FORT ST. DETROIT 16, MICHIGAN

(*Continued from Page* 32)

rocket's warhead, carrying almost 1000 pounds of electronic instruments to relay and record information about the outer atmosphere, was recovered intact 24 miles northwest of the launching site. The warhead is blasted away from the body of the rocket at the optimum altitude and then falls free. Its bulky unstreamlined designed serves as a brake in the heavy lower atmosphere.

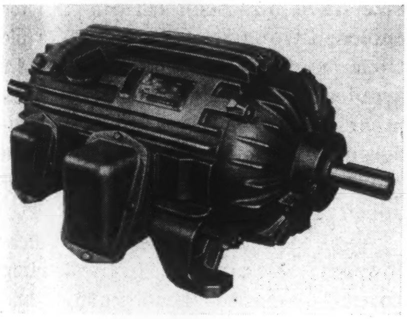
Major purpose of the flight was to measure properties of the ionosphere, the layers of charged particles surrounding the earth which reflect radio waves and make possible long-distance radio communication. A transmitter was carried aloft and sent radio waves through the ionosphere to receivers on the ground.

Other upper-air experiments were intended to determine the ion content of the atmosphere at high altitudes, its pressure, density and wind velocities. Emulsions prepared by the National Institute of Health were placed within the vehicle to detect cosmic radiation. The rocket also carried a number of cameras to determine its orientation during flight, to measure the intensity of the daylight sky illumination, and to obtain wide-area photographs of the earth's surface. Many of the instruments were devoted to measuring the performance of the rocket itself. Most of the scientific information obtained from the rocket was transmitted to the ground during the flight by means of a radio telemetering system.

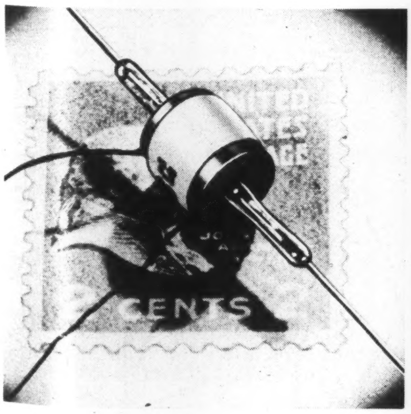
Mallory-Sharon Titanium Corp. has announced that it is now producing titanium ingots with its double melting process operated by remote control. The company, one of the major titanium producers, is now melting unalloyed titanium and a full range of titanium alloys, which are available in the form of sheet, strip, bars, forgings, and other mill products. Alloys include the MST-3Al-5Cr alloy, used by manufacturers of jet engines and airframe components, plus two new alloys, the 3 manganese complex alloy, and the 6 aluminum, 4 vanadium alloy.

New Enclosed Motor Makes Debut

Stator, slip rings, brushes and brush rigging are fully enclosed in a newly developed wound-rotor motor. Manufactured by Allis-Chalmers, the new motor is said to be the first totally-enclosed-wound-rotor type made.



By lengthening the front end, all of the associated parts normally outside the case are now enclosed.

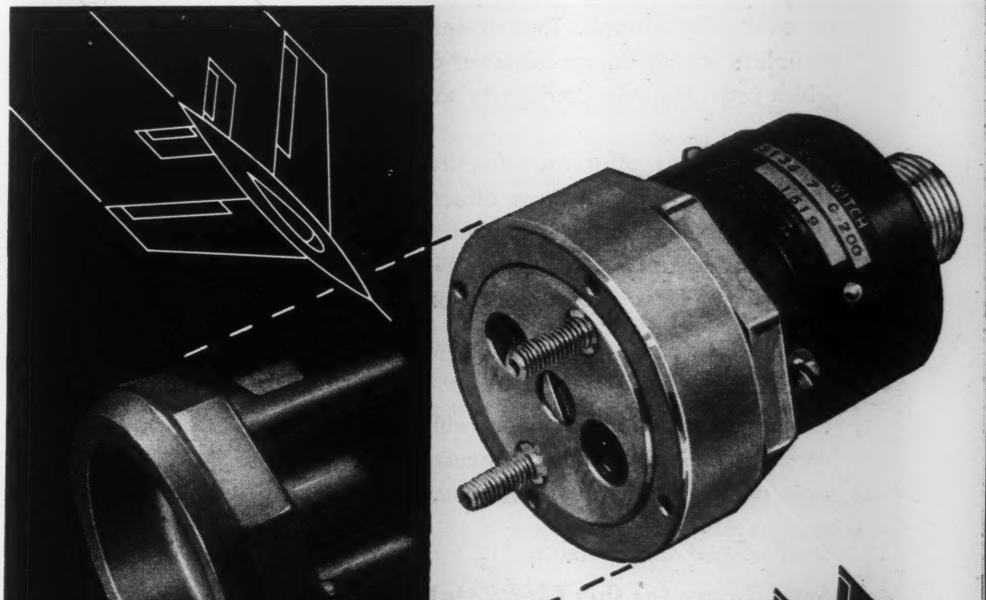


TINIEST RELAY in the world, according to its makers, G. M. Giannini and Co., can be actuated by a solar battery or photocell. Contacts and actuating elements are made of magnetic rods sealed in glass

MUELLER BRASS CO. forgings help insure dependable operation of aircraft pressure warning instruments

A specially designed housing, accurately forged to customer specifications by Mueller Brass Co., seals in the diaphragm of the pressure warning unit manufactured by Eclipse-Pioneer Division of Bendix Aviation Corporation in Teterboro, New Jersey. The unit, designed for installation in fuel, oil, water or alcohol lines of modern aircraft is a highly sensitive instrument that instantly warns the pilot or flight engineer of any unusually high or low fluid pressures.

All Mueller Brass Co. forgings have a dense, close-grained structure with a high tensile strength. Weight savings up to 40% are possible in the design of parts because of the close tolerances to which they can be produced. Less scrap and longer tool life result from the easy machinability of forged parts. Mueller Brass Co. is completely equipped to design parts for your products, specify alloys (including special alloys developed by our metallurgists), forge, machine, finish and plate the parts and perform all necessary assembly operations. Write today for our free illustrated 32-page forgings catalog and complete information about MBCo forged parts for your products.



MUELLER BRASS CO.

PORT HURON 15, MICHIGAN

PIONEER
Impeller Pumps
ROLLWAY
Positive Displacement
PUMPS

For Coolants,
Lubricants and
Abrasive Liquids

0 to 174 gpm

Something More Than
Quality and Performance

Rugged dependability and factory-tested performance are only a part of the story behind Pioneer and Rollway pumps.

For 23 years Pioneer has specialized in the design and manufacture of impeller and positive displacement type pumps. This experience led to the development of a complete pump line of over 400 models. The model shown above is one of a complete line of flange-mounted and submergible type pumps which provides strict conformity to J. I. C. standards.

Pioneer pumps offer manufacturers many important advantages, such as the savings effected through the selection of standard pumps to meet custom requirements. Another important consideration in selecting Pioneer pumps is the unusual opportunity for standardization and interchangeability.

Pioneer application engineers will welcome the opportunity to discuss your pump requirements with you.

Send Today for this *FREE* Catalog.

PIONEER PUMP DIVISION
DETROIT HARVESTER COMPANY
Sales and Engineering Offices: 14300 Tireman Ave. • Detroit 28, Michigan
Manufacturing Plant: Paris, Kentucky

Additional area for heat removal is also provided by the elongated frame. Large pipe plugs are removeable for maintenance work. Slip-ring leads are brought out to a separate conduit box and the lead opening in the frame is sealed.

Basically the APZ or APZZ rib-type frame, the elongated design permits use of standard bearing housings, external fans and fan housings as used on squirrel-cage motors in that frame construction.

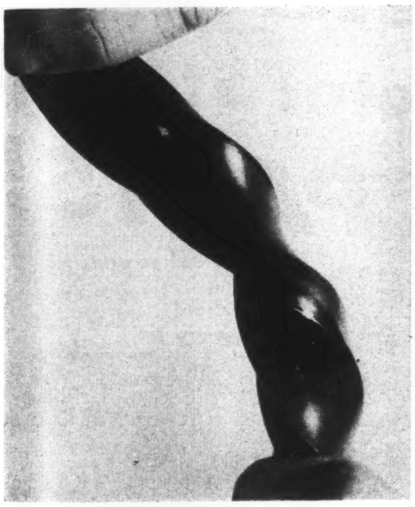
According to Allis-Chalmers, NEMA standards for horsepower and speed relationship to frame size have not been established for enclosed wound-rotor motors. While these motors are built on NEMA frames with standard mounting dimensions, they may be on a different frame than a squirrel-cage motor of the same horsepower and speed.

Applications include those where low starting current, high starting torque, smooth acceleration and variable adjustable speed combined with moist, dirty, corrosive or hazardous atmospheres dictate an enclosed wound-rotor motor.

MY Pencils
Glueckj
MACHINE DESIGN

Finished steel products shipped by steel companies increased 191,000 net tons in August over July to a total of 4,681,000 tons, American Iron and Steel Institute reported today. Thirteen of 20 industrial classifications took more steel in August than in the previous month.

The automotive industry took 656,000 tons in August, against 707,000 tons in July. This industry's total in eight months of 1954 was 7.4 million tons, against 10.7 million tons in the same period last year.



NEW TWIST at higher and lower temperatures can be given to organic rubber with the addition of a new silicone polymer. Called Dow Corning 410 Gum, the new polymer can be blended with or applied as a coating to organic rubbers to extend serviceable temperature limits and increase weather resistance

Silent Sound Solders Without Flux

Combining the cleaning properties of ultrasonic power with a soldering device, Aeroprojects Inc. has developed a new method of fluxless soldering. Aluminum, copper, magnesium and silver can be soldered without flux using this newly developed equipment.

Called Sonobond, the equipment

(*Continued on Page* 44)

SUPPLEMENT "A"
to
ACUSHNET RUBBER
DATA HANDBOOK

Please insert this Supplement in your copy of Handbook

Providing the Design Engineer with a relatively new method to simplify design, reduce costs and improve performance. The best properties of metal and rubber (natural and synthetic) may now be combined in one bonded unit to obtain strength, toughness and resiliency, as well as shock absorption, sound abatement, electrical insulation, corrosion resistance, protection against abrasion, etc.

ACUSHNET PROCESS COMPANY. New Bedford. Mass. U.S.A.
Precision Molded RUBBER *Parts & Products*

. . . *Send for your copy*

- INFORMATIVE
- AUTHORITATIVE

RUBBER-TO-METAL BONDED PARTS

Contents

- APPLICATIONS
- PROCEDURES
- DESIGN
- COMPOUNDING
- PROCESSES
- BOND STRENGTH RATINGS

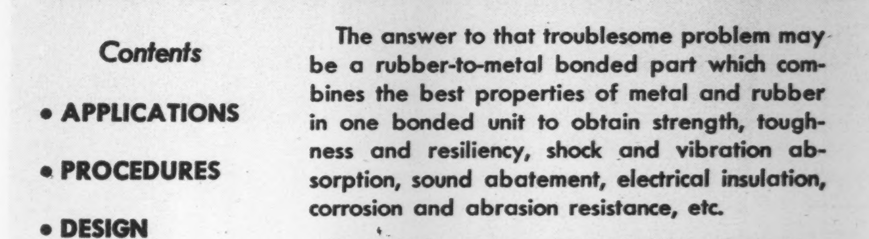
The answer to that troublesome problem may be a rubber-to-metal bonded part which combines the best properties of metal and rubber in one bonded unit to obtain strength, toughness and resiliency, shock and vibration absorption, sound abatement, electrical insulation, corrosion and abrasion resistance, etc.

Detailed information concerning this modern adhesion process is contained in the Acushnet brochure "Rubber-To-Metal Bonded Parts", a helpful guide available upon request.

Acushnet's specialization in this field involves the adhesion of rubber or synthetic rubber to metal in molds designed to accommodate the metal parts and which, in addition to bonding the rubber material to the metal, form and vulcanize the rubber in the same operation.

Acushnet
PROCESS COMPANY

As adhesion can be obtained on most metals, this process provides the design engineer with another method to simplify design, reduce costs and improve performance.



Address all communications to 762 Belleville Ave., New Bedford, Mass.

Qwik Change with PACKAGED Motor Starter PARTS!

EASY to Identify!

Easy-to-read catalogs, simplified motor control and overload relay selectors, illustrated service bulletins...these all combine to assure *quick changes* through easy parts identification.

EASY to Buy!

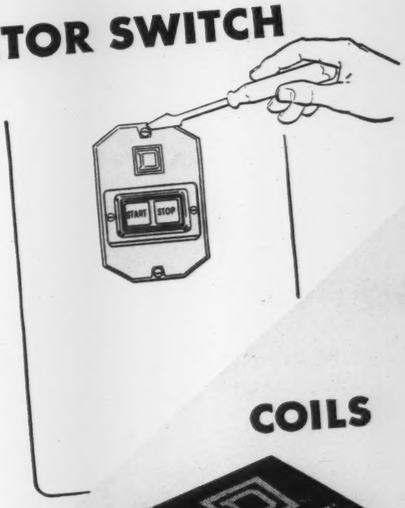
Conveniently packaged and labeled conversion parts are immediately available "off-the-shelf" from a nationwide network of authorized Square D electrical distributors.

Write **for Bulletin 9999. Address Square D Company,**
4041 North Richards Street, Milwaukee 12, Wisconsin.

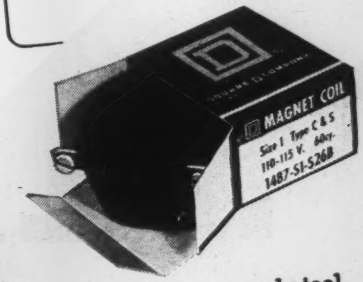
SQUARE D COMPANY

NEW PUSH BUTTONS AND SELECTOR SWITCH

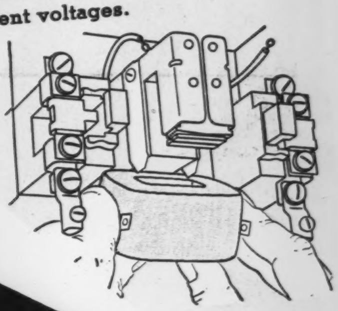
These Kits contain all parts necessary to make quick changes from standard starters to either push button or selector switch controlled devices.



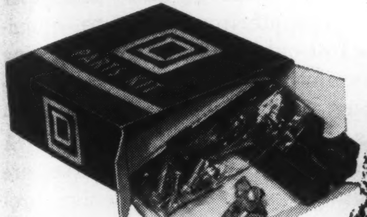
COILS


SQUARE D COMPANY
MAGNET COIL
Size 1 Type C & S
110-115 V. 60cy.
1487-S1-S26B

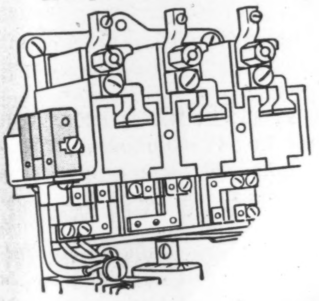
Screwdriver is only tool required for quick change of magnet coil to accommodate different voltages.



INTERLOCKS

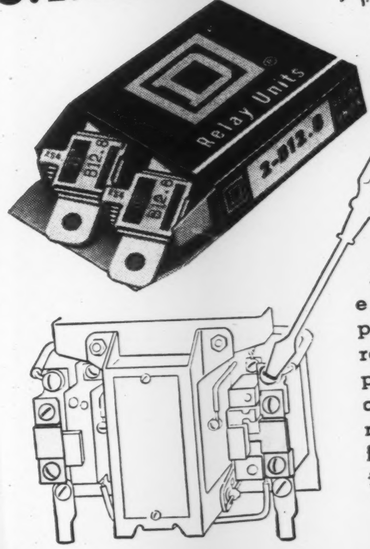


A wide variety of quick-change, front-mounted interlocks adds flexibility for special applications.



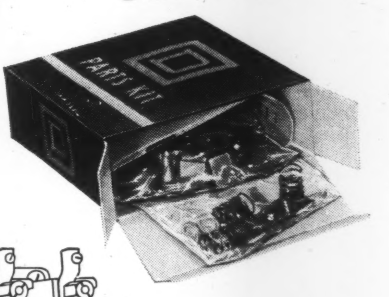
Faster to Install

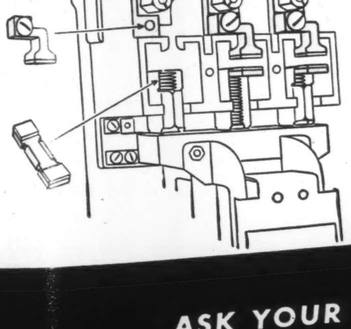
O. L. RELAYS


Relay Units
3-B12.8
B12.8

A wide variety of easily selected, packaged overload relay heater units provides quick changes to meet varying requirements for overload protection.

CONTACTS





Packaged replacement contacts are easily installed without disturbing wiring.

ASK YOUR ELECTRICAL DISTRIBUTOR FOR SQUARE D PRODUCTS

PRODUCT PERFORMANCE
AND ACCEPTANCE
REQUIRE CAREFUL
COMPONENT COMPARISON

Compare AEMCO RELAYS

OPEN OR CAN TYPE MIDGETS AND SUB-MIDGETS.

A WIDE VARIETY OF SPRING AND COIL COMBINATION, OPERATING POTENTIALS AND CONTACT RATINGS.

How do you compare relays? Comparison can be made on the basis of craftsmanship, uniformity of performance, dependability . . . and AEMCO invites such comparison. Comparative quality is relative but absolute quality is more certain!

We believe that the long and continuous servicing of more than one hundred top names of American Industry establishes the uniform dependability of AEMCO 'Engineered' RELAYS.

If one of the hundreds of stock AEMCO Relays does not exactly fit your requirements, we will design and manufacture to meet your particular needs . . . to *exceed your specifications!*

★ POWER RELAYS
★ DELAYED MAKE OR BREAK
★ CIRCUIT CONTROL
★ CURRENT AND POTENTIAL RELAYS

WRITE TODAY *for complete information on AEMCO Relays to meet your requirements and exceed your expectations!*

AEMCO
Automatic Electric MFG. CO.
64 STATE STREET · MANKATO, MINN.

(*Continued from Page* 41)

is said to be powerful enough for production use. Acoustical energy developed by the transducer is transmitted to the surface to be tinned and removes the oxide coating. An anodized coating will also be removed, permitting soldering to anodized or Alodized surfaces.

New designs utilizing joining of die castings or of copper to aluminum are now claimed practical. Soldering of sheet aluminum to many dissimilar metals, joining of aluminum tubing and dissimilar metals, soldering wires to aluminum foil capacitors and assembling of laminated aluminum sheet are among the many reported applications of ultrasonic soldering. A wide range of solder alloys are possible for particular design problems.

Fluxless soldering eliminates the need for a thorough washing to remove excess flux. Possible corrosive action of excess flux is also prevented.

• • • UNDERGROUND REACTOR *being built by Westinghouse for Duquesne Light Co. won't have any trouble keeping itself secret. Designers say there will be no tall chimneys, no smoke, no building for furnaces or boilers and no coal piles. In fact if you look real close, you might not see anything at all.*

Nothing to Invent? Look Over This List

Based on the fact that there is inherent in the American people a vast reservoir of inventive talent, the Inventors Council of the U. S. Dept. of Commerce is distributing a list of technical problems to the general public. Compiled in cooperation with the military services, the list contains 200 technical problems confronting the military as well as areas in which technological advances are desirable. Problems cover the fields of electronics, metals, materials and food.

A few typical examples are:

379 Improved metal

There is a need for an easily

worked alloy which will withstand temperatures above 5000 F.

383 Pneumatic tire substitute

Sponge rubber suitable for zero-pressure tires.

486 A personal heating system

532 Long-life batteries

537 Recorder for high-frequency range

Recorder for the frequency range of 5 to 1000 mc with immediate playback or long-time storage.

539 Frenquency-insensitive rotating joint

Rotating joint for coaxial and wave guide circuity.

551 Metal-to-metal adhesive

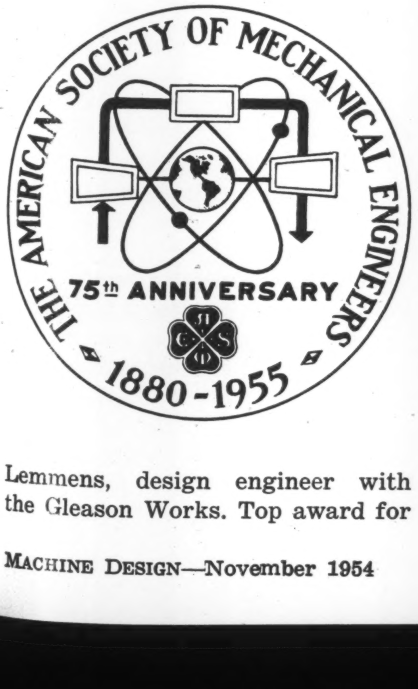
Increasing operating temperatures to 500 F requires a metal-to-metal adhesive having a shear strength of at least 2500 psi for aeronautical applications.

Details of the method of submitting solutions to these and other listed problems are published with the latest list. Copies may be obtained free of charge by writing the National Inventors Council, U. S. Department of Commerce, Washington 25, D. C. Ask for List 1954.

Symbol and Motto Winners Announced

Winners of ASME's contest to find a suitable symbol and motto for its 75th anniversary celebration have been announced.

Symbol winner was Andrew T. Lemmens, design engineer with the Gleason Works. Top award for


THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
75th ANNIVERSARY
1880-1955

Look what's happening in forgings . . .

Gear Blank
—upset forging

"COMMERCIAL" Metal Quality Forgings - are Tough !

You want your machinery to go from implement shed into the fields and back again—without down time. Breakdowns can be very costly because of crop loss. How important it is then, that the best materials known be used in all components of farm machinery to help head off rush season jams.

Massey-Harris has found the fibre-like flow line structure of forged steel the most satisfactory material for use in certain parts of their farm tractors. "Commercial" metal quality forgings are used extensively for parts subjected to great stress and strain. "Commercial" forgings made in closed dies which go into the differential and transmission of the Massey-Harris tractor have mechanical properties that can't be duplicated. Often "Commercial's" forging technique makes additional savings possible. The pierced continuous hole of different diameters in the forging in the picture reduced the amount of metal and lowered machining cost.

Should you have problems involving the use of formed metal parts requiring durability, efficient positioning of metal for required strength and finishing—let's see if "Commercial" forgings will not give you a lower cost by saving metal and eliminating rejects before any machining is done. "Commercial" are forging specialists who produce a lot of unusual forgings. We will be glad to assist in your design.

THE COMMERCIAL SHEARING AND STAMPING COMPANY
YOUNGSTOWN 1, OHIO • CHICAGO, ILLINOIS · SALT LAKE CITY, UTAH

"Commercial" engineers will gladly assist you; they have the experience and know how.

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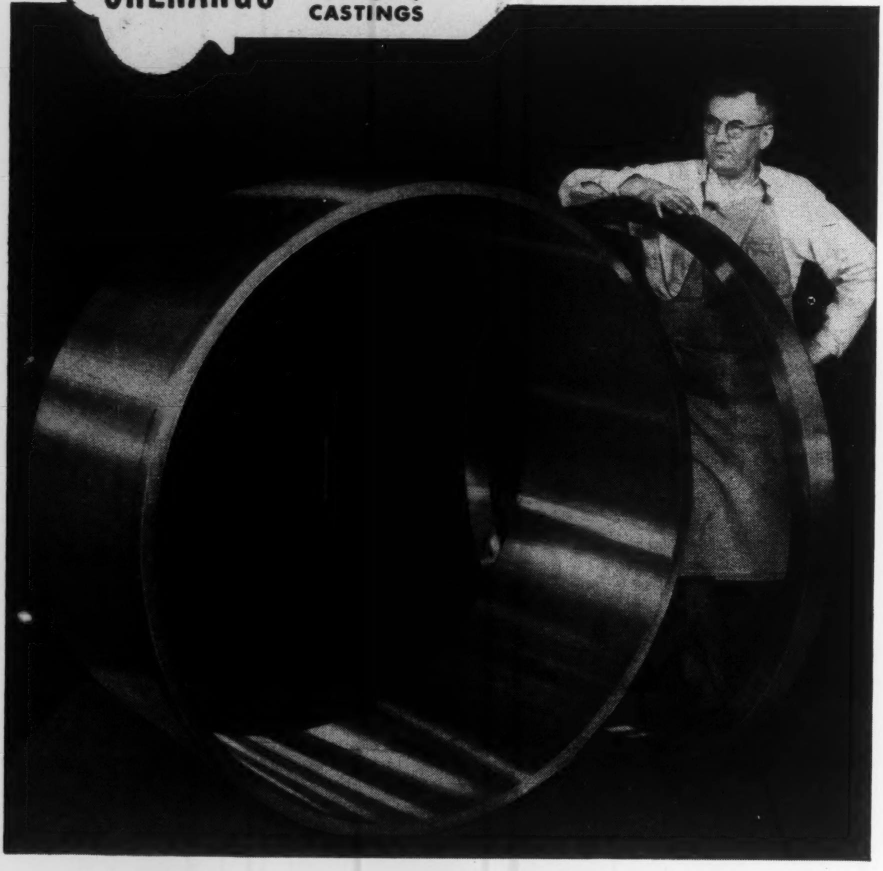
"PRODUCTS PREFERRED BY CUSTOMER ACCEPTANCE"

STAMPINGS • FORGINGS • TANK HEADS

FA-3

SHENANGO Centrifugal CASTINGS ... KEY TO SAVINGS



This big liner and seat ring were centrifugally cast of bronze "G" metal for use in a large hydraulic valve.

BIG in size
TOPS in dependability

REGARDLESS of size, you can put complete trust in Shenango centrifugal castings—rough, semi-machined or precision finished.

Because of Shenango's centrifugal casting process, you receive a uniform, close-grain, pressure-dense metal free from weakening imperfections. Other features include greater resistance to wear, better elongation and increased strength. All in all, Shenango castings, ferrous or nonferrous, are your best buy for any type of severe service.

The large liner and seat ring shown above are only two of the many varieties made by Shenango. For additional information on various size bushings, liners, rings, rolls, drums or almost any annular or symmetrical shape, address . . .

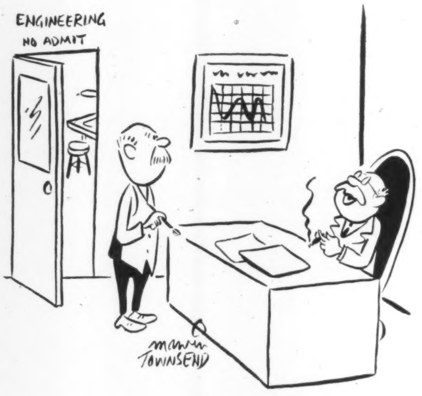
SHENANGO-PENN MOLD COMPANY
Centrifugal Castings Division
Dover, Ohio
Executive Offices: Pittsburgh, Pa.

SHENANGO

COPPER, TIN, LEAD, ZINC BRONZES • MONEL METAL
ALUMINUM AND MANGANESE BRONZES • NI-RESIST • MEEHANITE METAL

a motto was given David H. Ray, retired mechanical engineer of Tarrytown, N. Y. Each man received $250 first prize.

Design of the symbol represents the intersecting orbits of the atom, the traditional symbol for nuclear power, along with a representation of the thermodynamic cycle. The prize-winning motto was "By Truth and by Service."



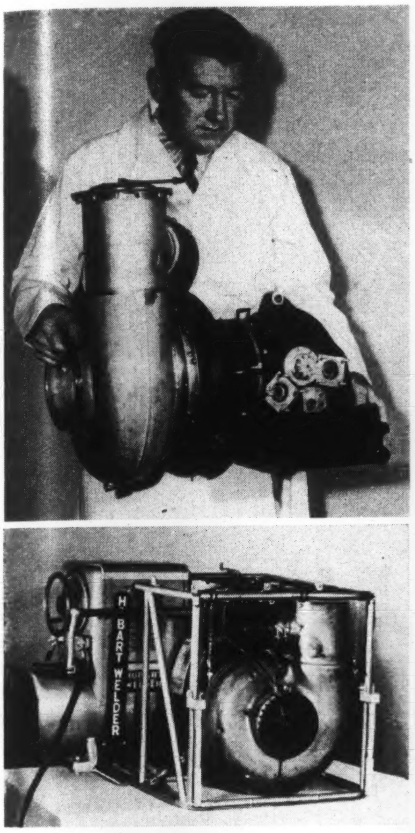
"I want you to know, Walter ol' man, that the fact you just inherited a half-million dollars has nothing to do with our promoting you from junior engineer to vice president."

Sintered Nylon Has New Design Possibilities

Unusually high distortion temperatures are said to give sintered nylon unusual design versatility.

Results of tests made by National Polymer Products Inc. indicate that this nylon material has a distortion temperature of 280 F at 264 psi. This high crystallinity imparts a low coefficient of friction and good dimensional stability. Ability to resist deformation under load at high temperatures is important because most nylon is used in rotating apparatus where it is subject to heating.

Bearings, cam rollers, valve seats and other industrial products are among sintered nylon's applications. It is especially useful for low-friction applications where lubrication is undesirable.



GAS TURBINE drives this new arc welder. Reported to be the first so powered, the unit is said to have the advantage of greatly reduced weight and size. Made by Hobart Brothers, the welder and turbine are expected to be the answer to lighter airborne welding equipment

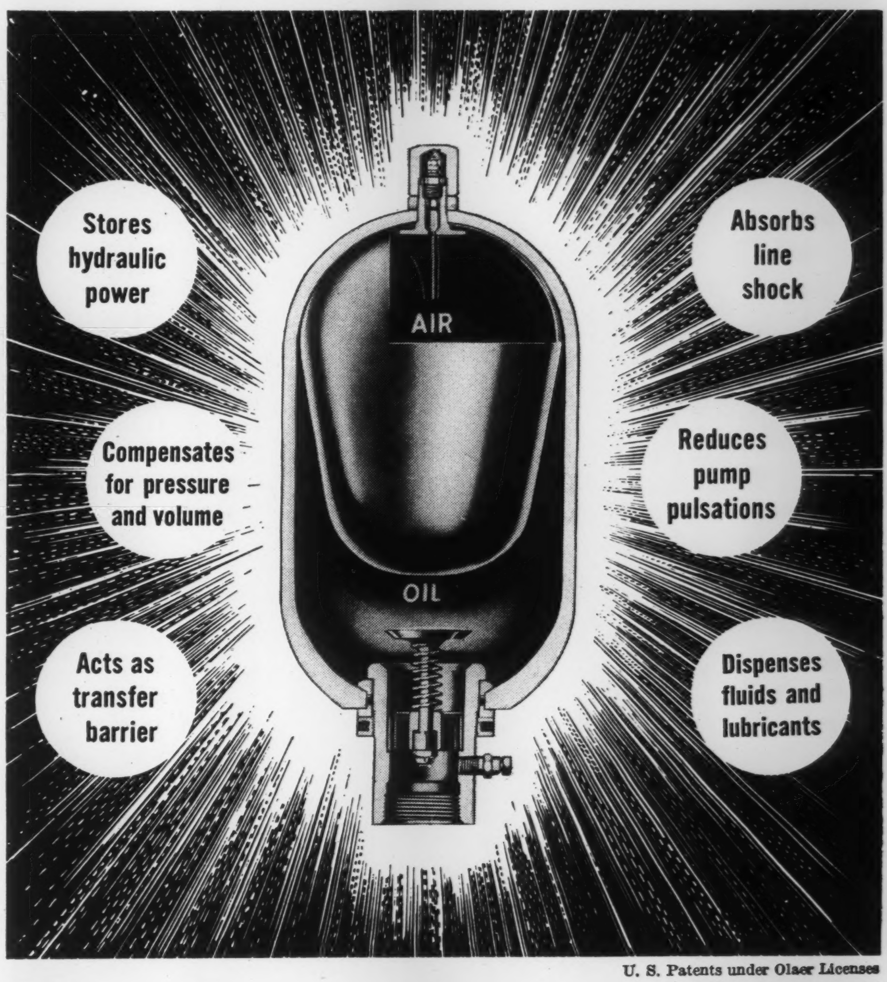
Extruded Pistons Are Lighter, Stronger

First extruded automotive pistons ever manufactured for commercial production are claimed to be 50 per cent stronger and 30 per cent lighter than the old-style pistons. Developed by the Light Metals Div. of Thompson Products Inc. the new product has recently been tested in a commercial engine.

Made of aluminum alloy fashioned by the impact extrusion method, the pistons are heat treated for a 100 to 200 per cent increase in tensile strength, greater ductility and over 400 per cent increase

(*Continued on Page* 50)

MOST VERSATILE HYDRAULIC COMPONENT EVER DEVISED!



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Today, Greer Accumulators are at work in almost every industry you can name. They are found in the hydraulic systems of buses, construction machines, ships, planes, submarines, and flying missiles. They power all types of presses, control steel processes, operate electric switches, absorb pulsations in oil pipelines—to mention a few of hundreds of applications.

Greer Accumulators can reduce the cost, size, weight, and complexity of your machines and equipment. And Greer's experienced application engineers know where accumulators belong for use, maximum performance and *complete* safety. Let them help you solve your hydraulic problem. Write or call Greer. No obligation. Brochure 301-A gives technical data on the Greer Accumulator. Ask for your free copy today.

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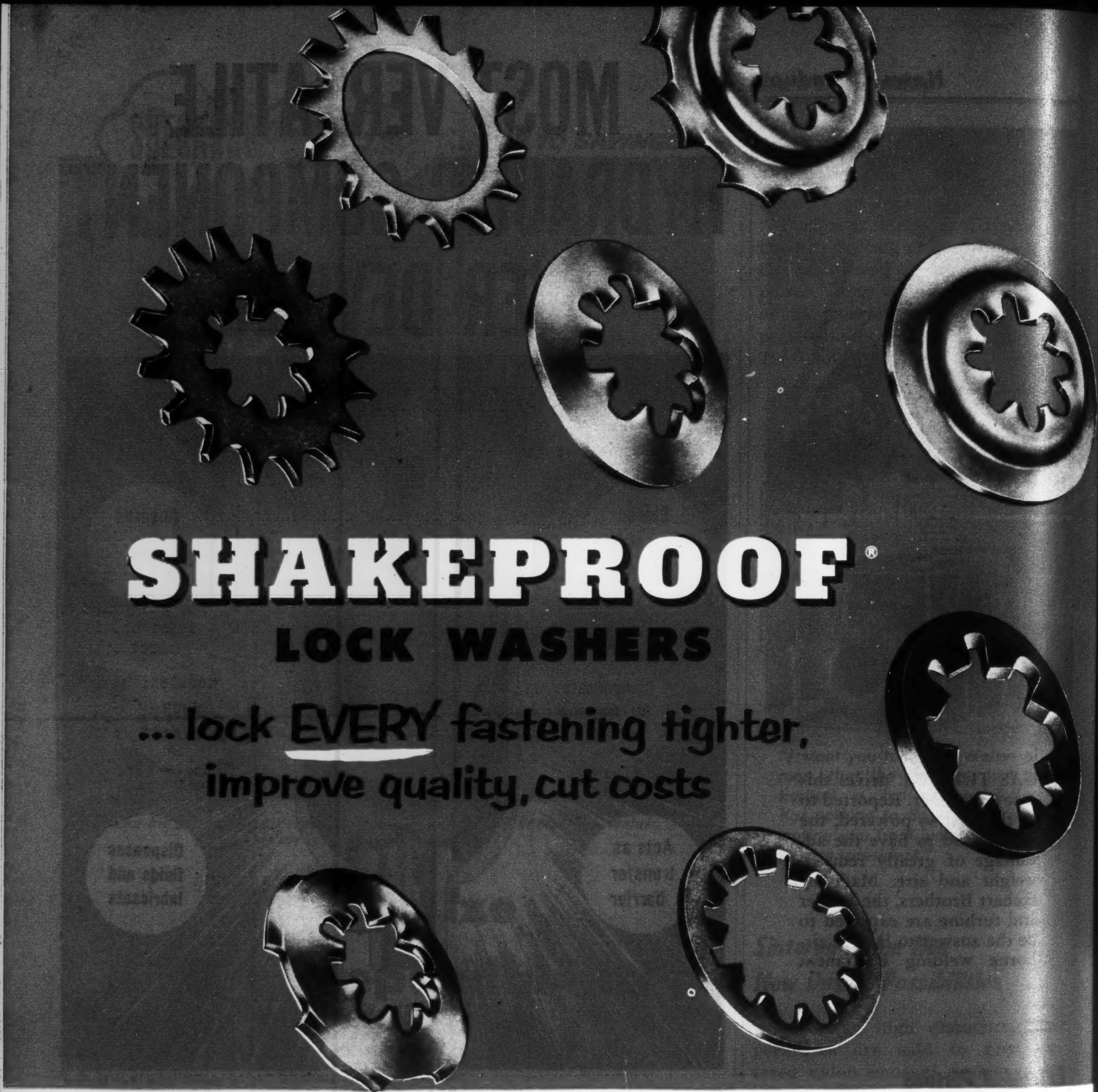
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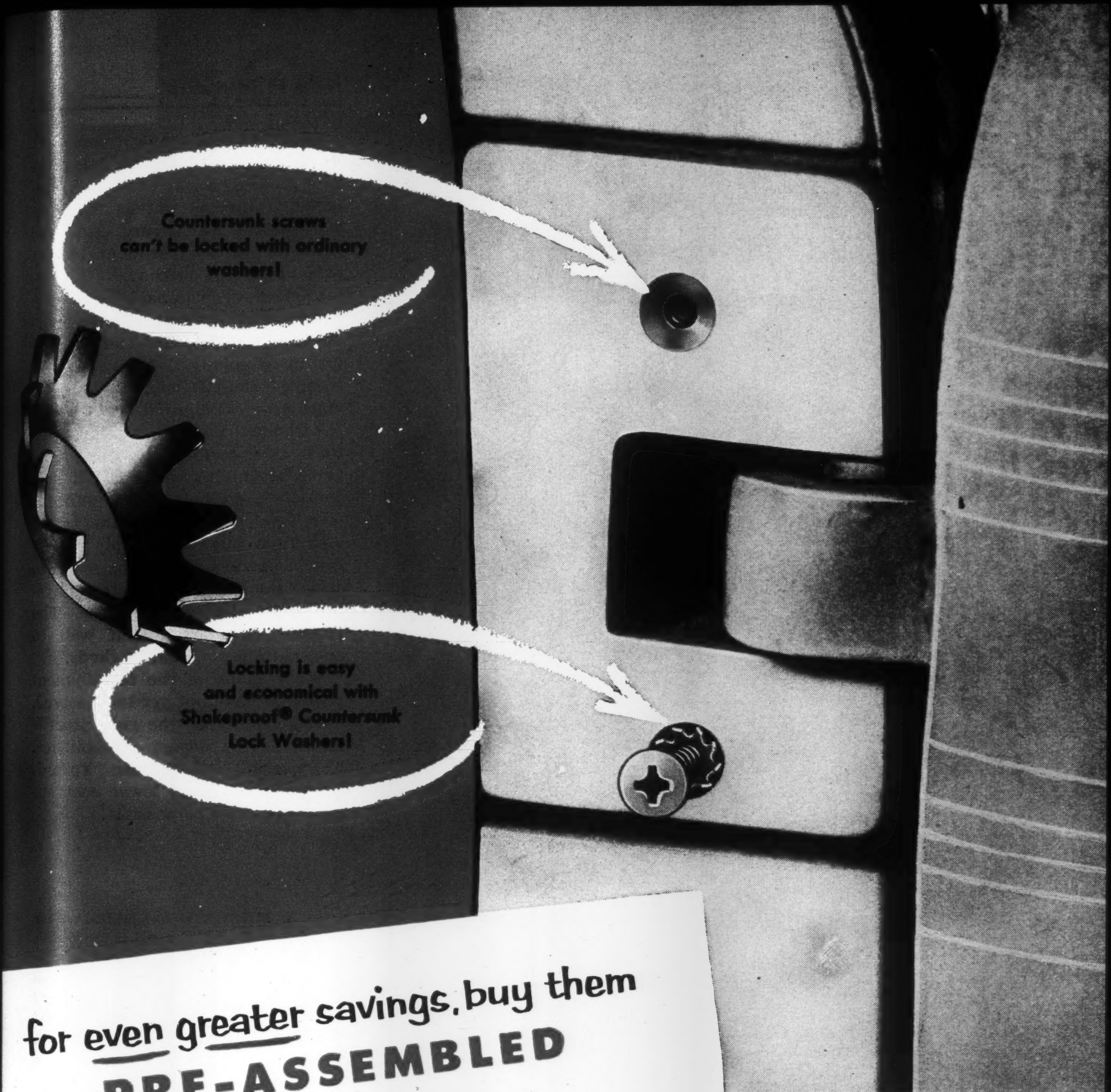
LOCK WASHERS
... lock EVERY fastening tighter, improve quality, cut costs

IN STOCK—TYPES AND SIZES TO MEET YOUR SPECIFIC LOCK WASHER NEEDS!

Locking a countersunk screw was a problem until Shakeproof developed Countersunk Type Lock Washers. Tapered twisted locking teeth give positive protection against loosening . . . put a stop to costly rejections and customer complaints due to loose screws. Assembly is faster, too, because screws lock tight at lightest touch . . . you get a perfect fastening every time!

Whatever *your* lock washer needs, there's a Shakeproof Lock Washer specifically designed for the job . . . designed to save costs and time on the assembly line!

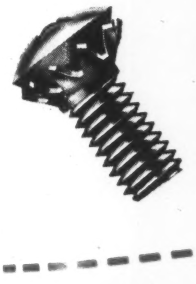
SHAKEPROOF
"Fastening Headquarters"®
DIVISION OF ILLINOIS TOOL WORKS
St. Charles Road, Elgin, Illinois • Offices in principal cities
In Canada: Canada Illinois Tools Limited, Toronto, Ontario


Countersunk screws can't be locked with ordinary washers!
Locking is easy and economical with Shakeproof® Countersunk Lock Washers!

for even greater savings, buy them PRE-ASSEMBLED

SEMS-BY-SHAKEPROOF

With Countersunk Lock Washers



All Shakeproof® Lock Washers can be pre-assembled with screws to eliminate separate washer handling . . . and reduce costs! You're certain to improve quality, too, because the lock washer can't be omitted.

KEPS®

Shakeproof also developed pre-assembled nuts and lock washers. They are fast, easy to use, always lock tight. With KEPS, every fastening is protected against vibration loosening.

TESTING SAMPLES
Shakeproof
LOCK WASHERS
SHAKEPROOF

FREE testing sample kit

Test Shakeproof Lock Washers on your own products . . . right in your own product laboratories. See how they lock even tighter as vibration increases; improve quality . . . and cut costs in your assembly. Send for your kit now.

GIANT MOLDS FOR CHIEF SANDUSKY . . . THE GIANT OF CENTRIFUGAL CASTING

When specifications call for ferrous and non-ferrous cylindrical castings —*call in Chief Sandusky.*

Making the finest cylindrical castings is a science and an art. Chief Sandusky has mastered the various steps which constitute it. Year after year "The Chief" is responsible for centrifugal castings that meet the most exacting requirements.

Solving metallurgical "puzzles" for users of cylindrical castings has always been a specialty of Sandusky Foundry and Machine Co. Proposing sound, practical answers for difficult problems is a regular procedure with Chief Sandusky.

First, there is immediate access to the company's own experts as well as to specialists in leading research laboratories.

Second, experience is one of the most valuable resources. And in the highly specialized field of ferrous and non-ferrous centrifugal castings Chief Sandusky is indeed resourceful, having over forty years' experience.

The best in cylindrical castings bears the name "Chief Sandusky."

C. M. LOVSTED & CO., SEATTLE, WASH. • TYNE BROS., BIRMINGHAM, ALA. • CORDES BROS., SAN FRANCISCO AND LONG BEACH, CALIF.

CHIEF SANDUSKY

CENTRIFUGALLY CAST FERROUS and NON-FERROUS RINGS, ROLLS, LINERS, TUBES, SLEEVES BUSHINGS, and BEARINGS.

SANDUSKY
FOUNDRY and MACHINE CO.

615 W. Market Street
Sandusky, Ohio

(*Continued from Page 47*)

in fatigue life. One man using the new process, is expected to be capable of turning out as many as 500 pistons per hour, compared with 100 to 200 per hour by the present casting method.

Casting of pistons by the permanent mold method requires pouring of the aluminum and waiting for it to solidify. After removal from the mold, trimming and finish machining is required.

Although impact extruded pistons also require trimming and finish machining, more rapid production is possible. After suitable dies are assembled in the press, aluminum slugs are simply fed in. Piston extrusions may be made to closer tolerances and better physical properties and structure. The process also lends itself well to automatic production methods.

While many of the development problems have not yet been solved, initial reports of the new process indicate new design possibilities. Engineering of higher speed, lighter weight and lower cost engines may now be possible.

• • • MECHANICAL ARM *made by General Mills Inc. is remotely controlled for handling work in nuclear laboratories, powder plants and generally where you wouldn't want to stick your arm. Shoulder, wrist and hand motions make it a handy accessory in a boarding-house dining room.*

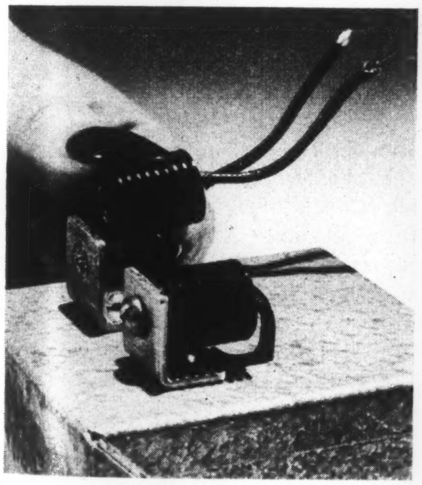
Floating Quiet Lab Checks Annoying Hum

A room floated within a room characterizes this new sound laboratory for low-level noise testing. Built by General Electric, the new laboratory is being used to test fluorescent lamp ballasts.

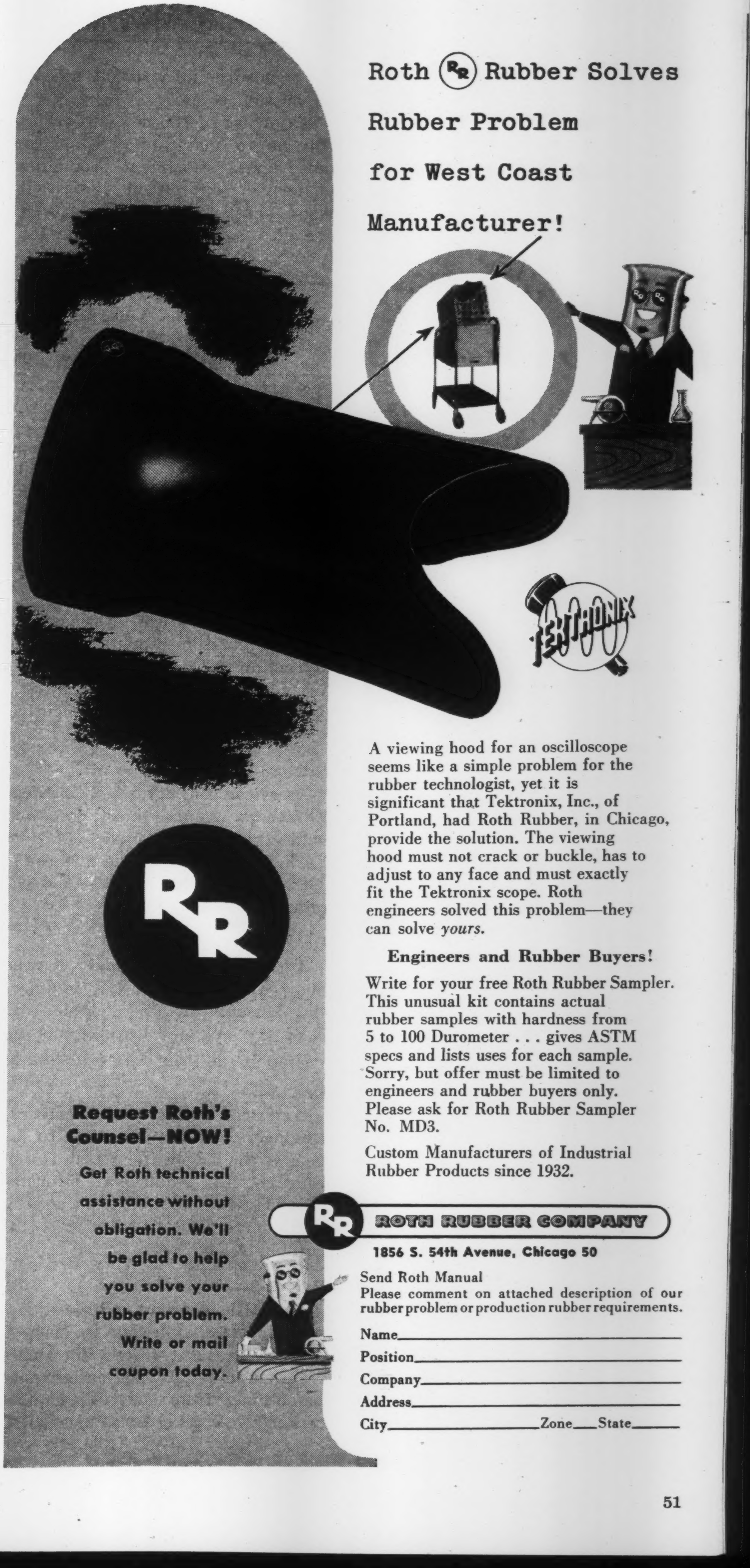
Walls, ceiling and floor of 8-inch thick concrete make up the outer room. A series of isolators support the inner room, thus minimizing any transmission of ground vibration. Poured concrete slabs, held together by concrete pilasters

Fluorescent lamp ballasts to be tested in General Electric's new quiet room are placed at the top of the plywood horn. Hum is picked up at the bottom by a sound level meter

and reinforcing rods, make up the walls of the inner room. Poured concrete ceiling and floor complete



MORE POWER TO YOU: Combining the black, ribbed design plus fastening the unit in thermal contact with the chassis gives greater heat dissipation and results in a higher powered transistor. Rated at 1 watt, these units are in pilot production by the Westinghouse Electronic Tube Division. They are expected to be used in amplifier service where high-power output is required



Roth Ⓡ Rubber Solves Rubber Problem for West Coast Manufacturer!

A viewing hood for an oscilloscope seems like a simple problem for the rubber technologist, yet it is significant that Tektronix, Inc., of Portland, had Roth Rubber, in Chicago, provide the solution. The viewing hood must not crack or buckle, has to adjust to any face and must exactly fit the Tektronix scope. Roth engineers solved this problem—they can solve *yours.*

Engineers and Rubber Buyers!

Write for your free Roth Rubber Sampler. This unusual kit contains actual rubber samples with hardness from 5 to 100 Durometer . . . gives ASTM specs and lists uses for each sample. Sorry, but offer must be limited to engineers and rubber buyers only. Please ask for Roth Rubber Sampler No. MD3.

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Please comment on attached description of our rubber problem or production rubber requirements.

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trouble spots
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the enclosure and virtually seal off all outside sound.

Major use of the new laboratory will be to maintain a check on noise levels of current production models of fluorescent lamp ballasts. New and experimental types are also sound rated by the lab.

Milwaukee Metal Working Co., over 50 years in the manufacture of hydraulic motors, pumps, valves and cylinders, has changed its name to Wisconsin Hydraulics Inc. L. G. Kranik, president, announced that the company will continue to expand with added personnel.

Meetings and Expositions

Nov. 15-17—
American Standards Association. Fifth national conference on standards to be held at Hotel Roosevelt, New York, N. Y. G. F. Hussey, 70 East 45th St., New York 17, N. Y., is managing director.

Nov. 15-17—
The Magnesium Association. Tenth annual meeting to be held at the Hotel Chase, St. Louis, Mo. Jerry Singleton, 122 East 42nd St., New York 17, N. Y., is executive secretary.

Nov. 28-Dec. 3—
American Society of Mechanical Engineers. Annual meeting to be held at the Statler Hotel, New York, N. Y. C. E. Davies, 29 West 39th St., New York, N. Y., is secretary.

Dec. 2-7—
Twenty-first National Power Show will be held at the Commercial Museum in Philadelphia, Pa. E. K. Stevens, 480 Lexington Ave., New York 17, N. Y., is manager.

Dec. 5-8—
American Society of Agricultural Engineers. Winter meeting to be held at the Edgewater Beach Hotel, Chicago, Ill. Additional information may be obtained from society headquarters, P. O. Box 229, St. Joseph, Mich.

Dec. 5-9—
Scientific Apparatus Makers Association. Fall meeting to be held at the Pinehurst Hotel, Pinehurst, N. C. Additional information may be obtained from society headquarters, 20 N. Wacker Dr., Chicago, Ill.

Dec. 12-15—
American Institute of Chemical Engineers. Annual meeting to be held at Hotel New Yorker, New York, N. Y. Additional information may be obtained from society headquarters, 120 E. 41st St., New York 17, N. Y.

Jan. 10-14—
Society of Automotive Engineers. Annual meeting and engineering display to be held at the Sheraton-Cadillac Hotel and Hotel Statler, Detroit, Mich. Additional information may be obtained from society headquarters, 29 West 39th St., New York 18, N. Y.

Jan. 24-27—
Plant Maintenance & Engineering Conference to be held at the International Amphitheatre, Chicago, Ill. Additional information may be obtained from the exposition management, Clapp & Poliak Inc., 341 Madison Ave., New York 17, N. Y.

Jan. 24-28—
Twelfth International Heating and Ventilating Exposition to be held at the Commercial Museum and Convention Hall in Philadelphia, Pa. E. K. Stevens, 480 Lexington Ave., New York 17, N. Y., is manager.

Jan. 31-Feb. 4—
American Institute of Electrical Engineers. Winter general meeting to be held at Hotel Statler, New York, N. Y. Additional information may be obtained from society headquarters, 33 West 39th St., New York 18, N. Y.

MEN

OF MACHINES

Consulting member of the Board of Engineers of Intertype Corp., Brooklyn, N. Y., **Ernst L. Midgette** has been appointed director of research, development and engineering. Mr. Midgette received B.S. and M.S. degrees in mechanical engineering from the University of North Carolina. He served as an engineer on the staff of the U. S. Rubber Reclaiming Co., Buffalo, N. Y., and later as an instructor in machine design at Johns Hopkins University. In 1946 he was appointed head of the Mechanical Engineering Department of the Polytechnic Institute of Brooklyn. He is a member of the American Society of Mechanical Engineers and the American Society for Engineering Education.

Ernst L. Midgette

Herman R. Freund, vice president, has assumed new duties as consulting engineer and supervisor of all typographic matters for the Intertype Corp.

Formerly chief engineer, **Sydney Minault** has been promoted to works manager of the Equipment Div. of National Research Corp., Cambridge, Mass. His responsibilities include the engineering department. **William O'Malley** has been appointed manager of engineering to succeed Mr. Minault.

The Gear Grinding Machine Co., Detroit, has appointed **William F. Wilson** to the position of vice president in charge of engineering and manufacturing. He will have charge of all engineering and manufacturing operations for all of the company's divisions. A graduate of Michigan State College, Mr. Wilson was previously associated with the experimental engineering department of the Hudson Motor Car Co., with Stevenson, Jordan & Harrison as a consulting engineer and, most recently, with Kearney & Trecker Corp. as works manager. Mr. Wilson is a member of the American Ordnance Association and the Engineering Society of Detroit.

A director and chairman of the board since 1946, **Henry O. Fuchs** is now vice president of Metal Improvement Co., Los Angeles. He has resigned the position of chief research enginer of Preco Inc., but will continue to serve this firm as a consultant. Mr. Fuchs was previously associated with General Motors Corp. He is the author of a number of papers and articles, including one entitled "Trapped Stresses," which appeared in the July 1948 issue of MACHINE DESIGN.

Taking charge of product research engineering and development, **V. L. Peickii** has been appointed director of research by National Motor Bearing Co. Inc., Redwood City, Calif. Before joining the company, Mr. Peickii headed a

The Ultimate in Labeling

Metal-Cal*

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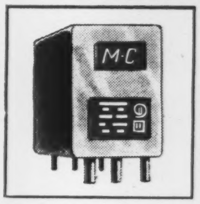

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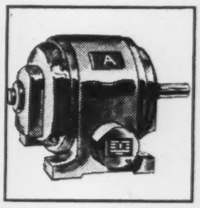
Any size or shape . . . in a variety of eye-catching colors with matte or shiny finish. Metal-Cals give prestige to product identification. No holes to drill — no screws or rivets to mar the surface.



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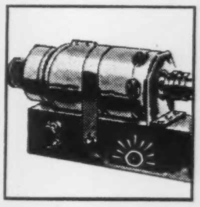
Weather tested from -100°F. to 300°F., government-approved Metal-Cals withstand extreme surface abrasion. Metal-Cals keep your instructions or diagrams like new forever



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Metal-Cals insure clarity in detailed reproduction. Ideal for the finest lettering or circuit detail for wiring diagrams...panel markings...component parts and finished assemblies.

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Metal·Cals adhere to any smooth surface . . . may be die cut to any shape.

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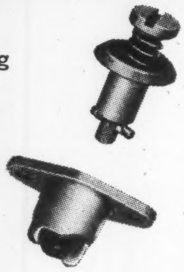
MEAN QUICK ACCESS. On panels, doors or covers, Camloc Fasteners provide positive locking by a quarter-turn with a screw driver or wing head. They're vibration-proof, because the action of cam, spring and detent creates a uniform locking torque that grips firmly. Camloc Quarter-Turn Fasteners cost less to install... minimize replacement... fewer do the job.



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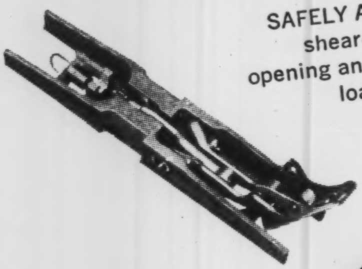
SAFELY AND EASILY OPERATED. Where high shear-tension capacity is a factor...where opening and closing must be done under heavy loads—Camloc has the answer. Spring-loaded handle, retracting sheer pin, positive locking are among the many design advantages.



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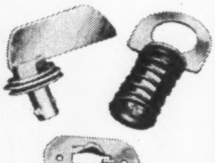
SUITED TO YOUR NEEDS. In the electronics, aircraft, machinery and many other fields, leading original equipment manufacturers are calling on Camloc's Engineering Department to design special fasteners that increase accessibility.



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A complete departure from conventional fastening.
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firm specializing in the design, development and manufacture of machine tools, instruments, oil seals and components for guided missiles. He also served as design development engineer for Crane Packing Co. and manager of tool engineering for Lockheed Aircraft Corp.

Robert H. Davies has been appointed vice president in charge of engineering for the Parker Appliance Co., Cleveland, and its subsidiaries. Mr. Davies graduated from the U. S. Naval Academy at Annapolis in 1934. He was a mathematics instructor at the New London Nautical Academy and later at Fenn College. He joined Parker in 1939 and was named engineering manager in 1946. Mr. Davies is a registered professional engineer in Ohio and California and is a member of the Society of Automotive Engineers, the American Society of Mechanical Engineers, the Institute of Aeronautical Sciences and the American Ordnance Association. He is the author of many technical articles and papers.

Robert H. Davies

The newly created post of chief of the engineering missiles section of Ryan Aeronautical Co., San Diego, Calif., has been filled by **A. B. Deyarmond.** Mr. Deyarmond was formerly chief of the technical section of the engineering division. **R. A. Fuhrman,** chief aerodynamics engineer, will assume additional duties as acting chief of the technical section. **Edward D. Sly** has been promoted to chief test project engineer.

R. H. Isbrandt recently was named chief design engineer of Nash Motors Div. of American Motors Corp., Detroit.

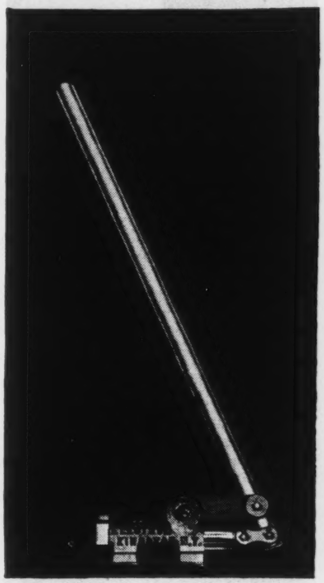
Formerly manager of the company's engineering laboratory at Poughkeepsie, N. Y., **Ralph L. Palmer** has been appointed director of engineering of International Business Machines Corp., New York. A graduate of Union College, Mr. Palmer joined the company in 1932. He served in electrical engineering posts at Endicott, N. Y., and in 1947 was made electronics engineer at the Poughkeepsie laboratory. He was named manager of this laboratory in 1950.

Other new appointments at I.B.M. include those of **John C. Abrams** as director of laboratory operations, **Jerrier A. Haddad** as director of advanced machine development and **James J. Troy** as director of product design. **Horace S. Beattie** has succeeded Mr. Palmer as manager of the Poughkeepsie laboratory, and **Francis E. Hamilton** has been named manager of the Endicott laboratory.

Ralph L. Palmer

Electrol
Hand Pumps
for Uniform
2-Way
Pumping Action

The Electrol 525 Hand Pump has a volumetric capacity of 1.5 cu. in. per cycle.



The Electrol 770 Hand Pump has a volumetric capacity of of 2 cu. in. per cycle.

Electrol Double-Acting Hand Pumps are capable of delivering uniform volume, with operating pressures up to 1,500 P.S.I. They are compact in design . . . have few moving parts . . . are low in cost . . . economical in operation. They have built-in suction and pressure check valves . . . ⅜" pipe thread ports . . . and can be used in mineral oil or water. Also, there are similar units available for use in gasoline, kerosene, or equivalent aromatic fluids. Complete engineering data can be obtained on request.

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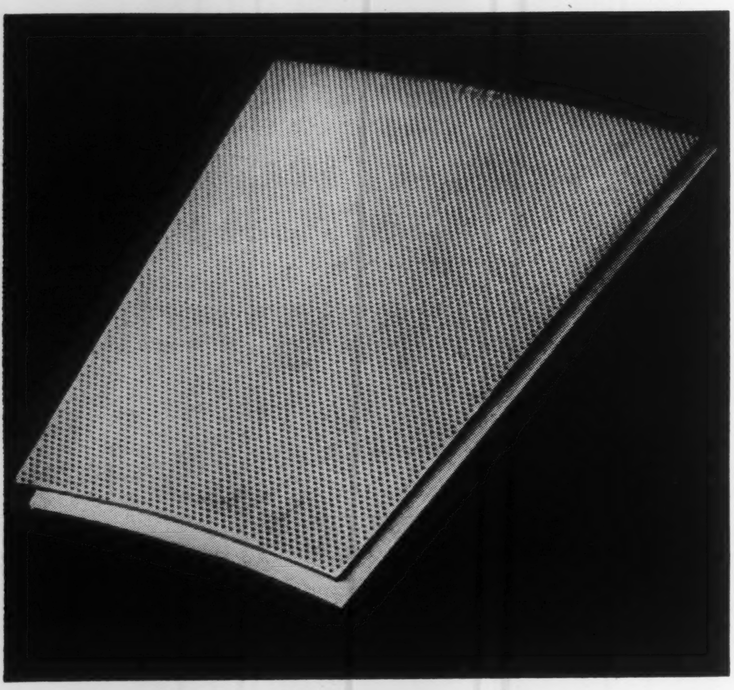
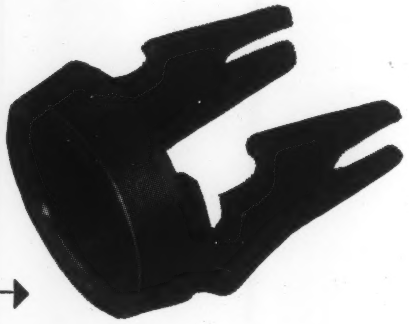
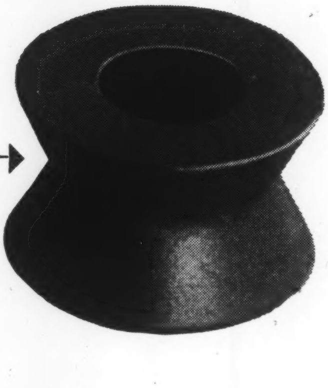
Trade-Mark



IMPROVED DESIGN AND MATERIAL—The tiny needle-sharp points covering this plate must resist severe abrasion. Machined points used to wear out frequently because they were pyramidal in shape and highly susceptible to erosion. HAYNES investment casting made it possible to cast the points in a more stable conical shape from a hard, wear-resistant alloy. Life has been increased by 5 to 12 times.



EXCELLENT SURFACE QUALITY—For sanitary reasons, not even the smallest crevice can be tolerated on this cream separator part. Because of the high quality of HAYNES investment castings, it was found that the intricate part could be manufactured on a production basis with a minimum of imperfections showing up during the final polishing operations. This eliminated a great deal of wasted time, work, and metal.



NO MORE MACHINING—HAYNES investment casting eliminated the job of machining these rollers. Service conditions require that the rollers be made of a special alloy which is difficult to machine. They must resist rusting and the cutting action of wire passing over them under tension. The rollers give excellent service life and there are no more machining problems.

HAYNES *investment castings can solve some of your own production and design problems. For more information, contact the nearest Haynes Stellite Company office listed below.*

"Haynes" is a registered trade-mark of Union Carbide and Carbon Corporation.

HAYNES INVESTMENT CASTINGS
Trade-Mark

Sound, dense, high-strength parts available in cobalt-base alloys, nickel-base alloys, iron-base alloys, stainless steels, and alloy and carbon steels.

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MACHINE DESIGN
NOVEMBER 1954

Vigilance Needed

ON THIS PAGE, last month, we observed that engineers, with all their organizations, are failing to achieve the unity enjoyed by other professions.

Because engineers serve largely through employment in industry, their profession differs from others such as the medical and legal. The number of engineers in industry has risen rapidly. They now represent a sizable proportion of industrial employees. Two implications of this fact are important: the individual tends to become submerged, and the group becomes attractive game for zealous labor organizers.

Fortunately, labor laws are now so written that engineers can be independent of industrial or trade unions in the same plant. But some have seen fit to organize for collective bargaining with their employers. Those who do should ask themselves whether their actions will strengthen or weaken the profession, and their own futures.

A few simple tests will quickly establish whether a group operates on a professional level. For instance, does the group recognize and support these principles:

1. Personal responsibility of each member to complete as quickly as possible a job once undertaken
2. Obligation to regard as confidential any matters which an employer so designates
3. Restriction of membership to those whose work requires the exercise of discretion and judgment not subject to standardization
4. Advancement and promotion through merit rather than solely through seniority
5. Furtherment of professional knowledge, ideals and practice
6. Obligation to society and to fellow engineers.

The real key to the future status of any profession lies in the attitude of the individual members. Because engineering is less highly organized than some other professions, the obligation on each individual is all the more pressing. And the preservation of professional standards will continue to demand the utmost vigilance on the part of every engineer.

Colin Carmichael

EDITOR

DEVELOPING CREATIVE TALENT

By E. G. Reed *Director of Research, Originality House, Akron, Ohio*

SUCCESS in creative engineering depends on trial. To know that an idea works is more important than to understand the principles involved, since a new device or invention may use principles that are not currently recognized. Because the inventor is not too greatly concerned with principles and logic, he simply tests any idea relating to the solution of a problem to obtain a sense of direction.

This process involves a method of creative thinking that can be reduced to a recognizable technique. A recent study of successful inventors has emphasized the striking similarity of their methods. This consistency lends strength to a general acceptance of the belief that there is a definite "method" of creative thought which can be followed. With command of these techniques inventive talent can be developed with some certainty of results.

Primary in any discussion of creative-engineering thinking processes is recognition of the difference between research and invention:

Research is logical. It follows the routine of geometry where, starting with axioms, each conclusion is based on a previously proved conclusion. The most obvious flaw of the research method, when used alone, lies in the fact that a single mistake in its long, complicated line of logic, or a single false assumption, can invalidate its conclusions.

Invention is psychological. It requires the coordinated use of certain basic abilities. Each ability is related to a definite mental and emotional approach. Contrary to general belief, inventors are very normal people who have acquired a technique of thinking most likely to produce creative results.

What are these basic abilities? For convenience, they can be considered as six definitely recognized mental processes. Each is necessary for successful development of inventive talent, but may not be labeled as such by those who follow the procedure. By conscious development of each step, however, inventive talent can be improved.

Obstacles to Creative Talent—1
Smugnosis

Smugnosis is a disease of the judgment in which the individual arrives at negative conclusions with insufficient information. The greater the formal education, the greater the susceptibility to smugnosis. Less than ten years before the first atomic explosion, an internationally known scientist and authority on atomic energy stated publicly that a thousand years of research and development would be required to develop an atomic bomb. Later, an equally famous scientist stated that the chances were a hundred to one against development of a hydrogen bomb. (Parenthetically, neither have ever been accused of Communist sympathies.)

Creative effort is the basis of all successful design engineering. Creativeness or invention, however, is a function—not of logic or reasoning—but rather of the personality traits and psychology of the individual. The proper climate for creative engineering can be supplied; incentives can be offered; training programs can be sponsored. But the success of any program rests squarely on the individual's own creative talent, and the successful development of a personal technique for creative thinking. This technique may vary from person to person, and certainly the mental processes involved defy simple analysis. One approach to the problem is considered in this article. Several facets of the discussion will intuitively be recognized as completely valid by everyone who has experienced the pain and labor of creative effort. Other facets may be highly controversial. But conscious attention to individual development of a technique for creative thinking can pay dividends, no matter what the route.

EDUCABILITY

Educability differs from education even more than research differs from invention. In some instances, too much education decreases educability. Memory is necessary to modern formal education. But selective memory or ability to forget—a far more difficult trait to acquire—is essential to educability.

To have a high degree of educability the things we do not know must first be recognized. Only when the vast chasm of human ignorance has been viewed will educability be increased for the things we think we know.

The second aspect of educability is the ability to distinguish between fact and opinion. All accepted scientific principles are opinions subject to revision and change when additional facts are

Obstacles to Creative Talent—2

Too Young? Too Old?

An erroneous belief, brought about largely by statistical analysis, is that the peak of inventive genius is reached before the age of 35. There is no real evidence of decrease in creative talent in later years. Youth establishes his status as an inventor through his willingness to take chances. Once established, he becomes afraid to add further ideas, lest he lose this status.

Young people have very high creative ability which, with proper encouragement, will not decrease as they grow older but will remain through the years if kept active. Often this creative talent is stifled by cramming young peoples' minds with nonessentials and inhibiting the development of original ideas. The creative power of youth has never been fully exploited.

One of the greatest reservoirs of creative talent untapped by management today lies in this combination of the minds of the teenage and past-fifty groups.

discovered. Too many engineers and scientists assume that acceptance of a principle by leading authorities makes it necessarily factual. Thus, educability might be termed the ability to doubt "established" facts, even the axioms, unless proved in practice—and to try new approaches.

PERCEPTION

One of the most important functions of perception as related to creative thinking is ability to distinguish between things as they are and as they should be. Lack of this ability has always been a major obstacle to human progress.

Very few people can see beyond their own immediate interests. Yet the ability to see beyond immediately obvious facts and opinions is absolutely essential to inventive technique.

Ability to distinguish between what is happening and what should happen, to see trends, to realize when old and generally accepted concepts have served their original purpose, provides the basis for the proper statement of problems to be solved and descriptions of machines to be designed. Invention provides for the future, so the principles used in an invention should be those that will be acceptable in the future.

ANALYSIS

Analysis, one of the last of the basic abilities to be developed in man's evolution, operates like a machine, without emotion or responsibility. It is the most ruthless kind of thinking.

Consistency is extremely important in analysis. Since man's mind operates under the laws of psychology, and not logic, few people are consistent. Most scientists are not bothered by the fact that the principles accepted in one science may be denied in another. This natural lack of consistency and fixed purpose in the average person makes analysis extremely difficult and fatiguing.

Analysis plays a double role in invention. Most obvious is that of making a sufficiently fine breakdown of a problem, so that at least one of its parts is easy to solve. While the primary purpose of analysis is to simplify a problem rather than solve it, sometimes parts of the unsolved problem correspond to parts of solved problems, so that the solution lies in comparison to that which has already been done.

If all parts are handled in this manner, the complete solution will follow the routine of research. On the other hand, if parts remain that cannot be solved by comparison to accepted procedures, this preliminary analysis will have clarified the part that remains to be handled by creative effort. In most cases, the creative solution will provide an easy, and usually unorthodox, way out of difficult situations. Analysis is essential to the proper setting up of problems to be solved.

The second and less obvious role of analysis is that of preparing the mind for creative thinking. Prolonged analysis produces an emotional state that ultimately induces a high degree of sensitivity to new ideas. This sensitivity, as a rule, is preceded by a period of discouragement. The inventor's experiences parallel those of a long-distance runner breaking through the barrier of fatigue into a "second wind." Analysis provides the necessary conditions for this breakthrough into a fresh mode of thought about the problem.

Few scientists or engineers experience the exhilaration of creative thinking. They relax at the wrong time and in the wrong way. Many people doing strenuous analytical thinking develop habits —conscious or unconscious—that provide a degree of diversion from mental fatigue, such as handling a pipe. By such diversion, however fatigue is held at such a low level it cannot trip the trigger of nervous mechanism necessary to creative thinking. Even when the fatigue barrier is broken, these diversions, used to reduce the mental strain of analysis, interfere with creative thinking. The creative inventor relaxes just as much, but at the right time and in a different way.

Obstacles to Creative Talent—3
Acceptance of Failure

Accepting a failure can prove to be a serious mistake. Each failure must be checked carefully, for a thousand failures only prove that a thousand wrong ways have been tried, while the thousand and first might succeed. There is value in both success and failure.

CREATIVENESS

Creative ability, one of the first basic abilities to be used in man's evolution, is based on a thought process in which judgment and logic are absent. With true creative thought, ideas are never thought of as right or wrong but merely accepted as ideas. The moment judgment begins to evaluate these impressions, creativeness ceases.

Creative ability grows out of the fatigue of analysis. Immediately after thorough analysis of a problem, in which a certain amount of mental fatigue and frustration has occurred, the inventor tends to arrive at a state of alert relaxation in which his senses are tuned to impressions that seemingly have little connection with logical thinking. Once this state is achieved, many solutions to the problem occur almost automatically. When one has learned to "tune in" this mental state at will, the feeling develops that any problem that can be clearly stated can be solved as simply as turning on a television set. One is constantly aware that the conscious mind does not provide these solutions.

The secret of creativeness seems to lie in the ability to utilize as yet little-understood sources of thought, and to eliminate the interference of one's conscious thoughts. Can this "tuning in" be done, at will, by the average person? The answer is "yes," if he masters the art of alert mental relaxation and the ability to distinguish and be sensitive to these impressions.

Fatigue, which helps trigger the creative state, can be induced by prolonged physical and mental work, just as one uses fatigue to induce the second wind. Perfecting this ability is not easy.

Alert relaxation, which is an integral part of the creative state, starts with body relaxation which ultimately affects brain action. Mental exercises include attempting to stop the conscious thinking processes, leaving the mind alert to the influx of new ideas. Usually this can be accomplished for only short periods of time. However, it is in these intervals that the first creative thoughts occur.

Creative Group Thinking: Creative group thinking is quite different from ordinary group and panel discussions. It follows a pattern similar to that of research, in which one idea grows out of another, yet highly trained research men might have great difficulty in carrying out true group thinking.

The secret of group thinking is in planting ideas in anothers mind, like the cowbird that lays her eggs in anothers nest to be hatched. Creative group meetings are usually started by someone stating the problem to be solved and suggesting a solution in such a manner that each person in the group feels either that he could have stated a clearer solution or that he has a better idea. No-one criticizes another's ideas. Not only must every individual recognize the possible merits of ideas already proposed, but he must add to them in such a way as to plant an idea in the minds of the remaining group. His skill as a group thinker is measured by his ability to state his contribution in such a way as to cause others to think.

By the time an idea has been passed around a group several times the results are surprising, and few can determine their own contribution. As soon as one approach to a solution is exhausted, a new one is started, and the process is repeated until a number of possible solutions are developed. At this time they are reviewed and evaluated, and a course of action is planned.

Obstacles to Creative Talent—4
Restrictions and Red Tape

Departmental and individual restrictions, overspecialization, red tape, and the thousand-and-one formal routines required on many jobs are all hindrances to inventive talent. A certain degree of flexibility of working methods and arrangements is necessary; too formal a setup not only restricts initative, but all too often provides an escape from the labor of creative thought.

JUDGMENT

Judgment has the task of determining which of a number of possible solutions to each problem, is the most practical, and if the solution meets all the requirements. If not, the unsolved parts are sent back for reanalysis, and the cycle of analysis, creative thought and judgment is repeated until every phase is completely solved. The sole function of judgment in this cycle is evaluation of ideas after they are fully developed, and not before. Judgment does not involve censorship of ideas.

This task seems very simple, since judgment must only keep out of the way until a number of solutions have been worked out and then evaluate them. However, good judgment is very rare. Even highly trained members of the Supreme Court, with well-established rules of procedure, are not always able to reach the same conclusions from the same facts. Also, the naturally tendency to judge with insufficient evidence interferes. Those with poorest judgment sometimes have a confidence born of ignorance that prevents them from recognizing and correcting their own weakness.

To develop good judgment, one must first understand all obstacles to accurate decisions, including recognition of his own personal faults in judgment. Hasty judgment should never be made on negative evidence. Practice should be in fields where conclusions can be checked against accurate measurement, rather than against opinions of those whose judgment may be faulty. The tendency to oversimplify, leaving out essential considerations, may be lessened by increasing one's general knowledge, thus enlarging the number of possible comparative sources for conclusions. Judgment should never be used when a decision can be based on measurement.

INITIATIVE

Initiative is by far the most important of all abilities related to creative thinking. Without it the inventor becomes an impractical dreamer. Initiative alone can take one a long way toward success.

Initiative usually involves a strong urge that will not permit the individual to rest until the desired goal is reached. A wide variety of emotions may occur in the process. Under favorable conditions, initiative induces enthusiasm and confidence. Under unfavorable conditions, a dissatisfaction with these conditions, and a drive to overcome them is likely to be produced. Because of this emotional versatility, true initiative is hard to stop.

Inspiration should always be followed by action. A good method of developing this forward approach is to set up a worthwhile task, then place oneself in a position where it will have to be carried out or ridicule will result. Correcting an undesirable habit is a good beginning exercise for this purpose. The selected task should always be difficult but within one's capacity. After each success, a more difficult plan should be attempted until the individual has convinced himself by his own accomplishments that he can meet any situation.

Conclusion: This is only one method of invention. Invention can be methodical, so much so that every individual can develop a technique best suited to his needs. But all invention follows a definite pattern. It's not the method but the results that count.

They Say . . .

What industry is trying to say to educators concerning the engineer and the scientist is this . . .

Give us well-founded men.

Cultivate habits of mind that will enable them to seek out unsolved problems, to systematically explore, and where possible to add to useful knowledge.

Give them basic tools in the form of fundamental knowledge for this task, but above all show them how to acquire more tools for themselves as they reach the limits of their past training.

Encourage qualities of initiative and responsibility.

Make them aware of the economic evaluation society will inevitably put on their contributions.

Help them toward attitudes of co-operation with their associates in work and community because much of their lives will be spent in working with and for people.

Prepare them to better adjust to people, situations, and the changing complexities of our society.

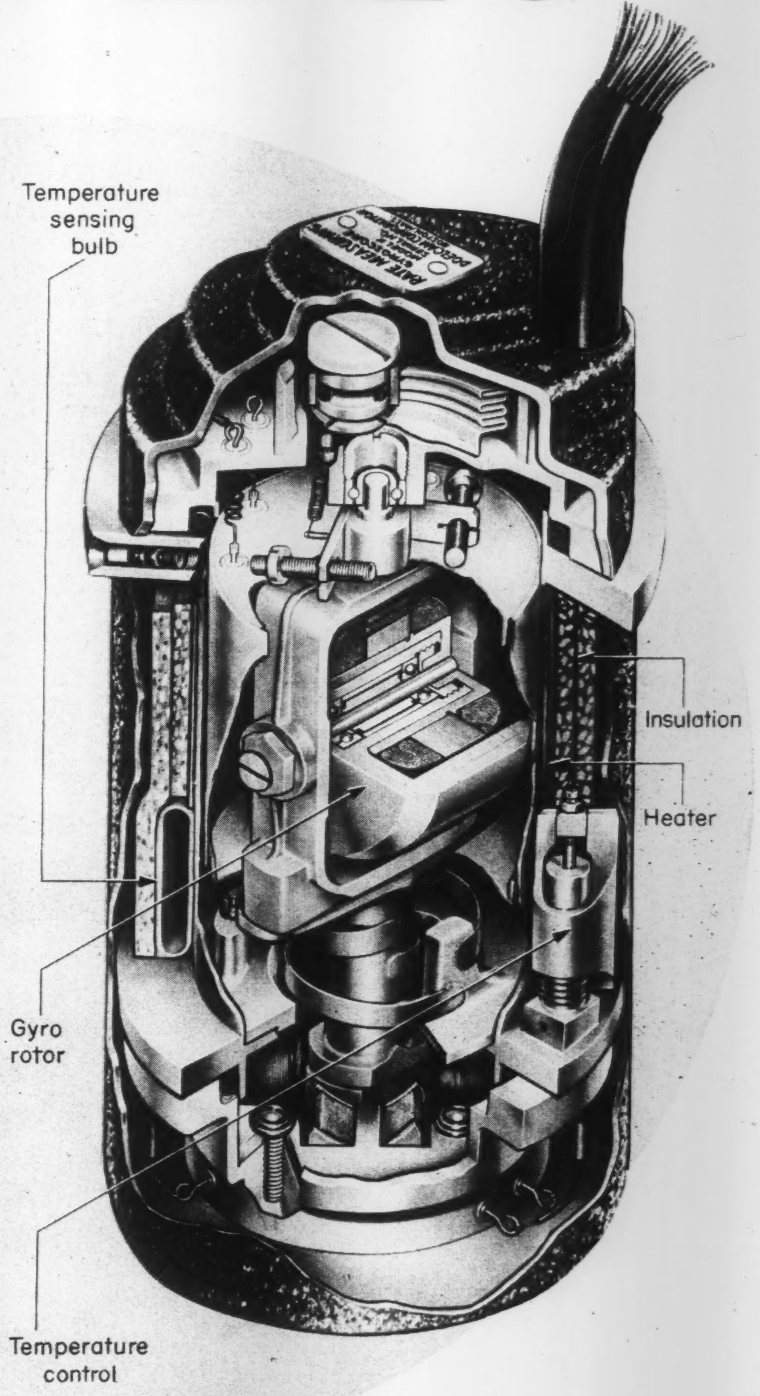
Foster alertness to broad social trends and the implications these have to their field of work. —W. SCOTT HILL, "Observations by Industry on . . . Educating the Technical Graduate," *General Electric Review,* July, 1954.

"The mark of a good mechanical engineer is his ability to remove an element from a mechanical system, and at the same time improve the performance of the system. An element of a system cannot be classed as necessary until you have attempted, without success, to remove the element." —F. R. BENEDICT, *assistant engineer manager, Westinghouse Electric Corp.*

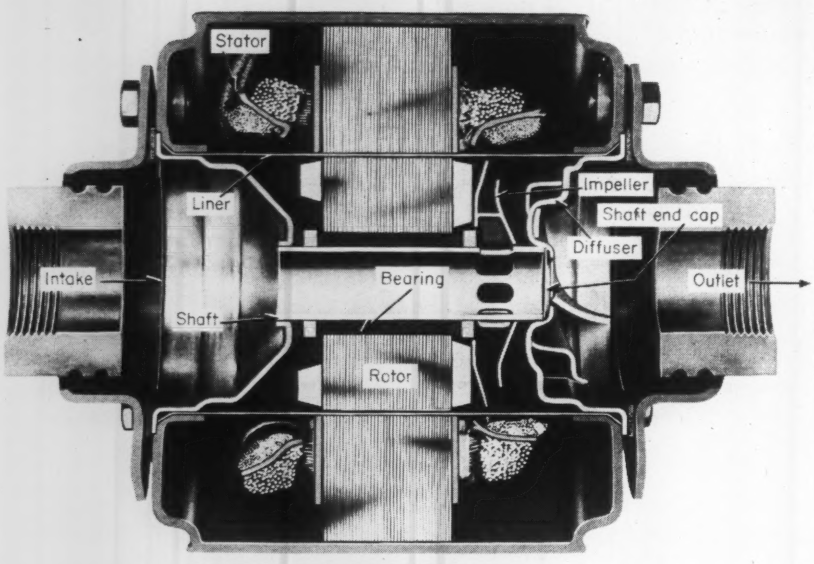
"It is in the tradition of science first to *observe,* then to *understand,* and finally, to *utilize* the forces of nature."—LAWRENCE R. HAFSTEAD, *director, Div. of Reactor Development, Atomic Energy Commission.*

SCANNING the field for IDEAS

FLUID DAMPING of rotating precision instrument assemblies improves dynamic response characteristics and offers protection against shock and vibration. In a rate-meauring gyroscope developed by Doelcam Corp., torsional oscillations of the gimbal assembly are controlled by silicone damping fluid between the cylindrical container for the gimbal assembly and the gyro casing. When maintained at the proper temperature, the silicone fluid provides the ideal viscosity compromise—sufficient to damp the torsional oscillations and yet not enough to hinder gyro response to input signals. Temperature of the fluid is maintained by an electric heating unit, immersed in the fluid, which is controlled by a sensitive thermostatic unit for fast response to small temperature deviations.

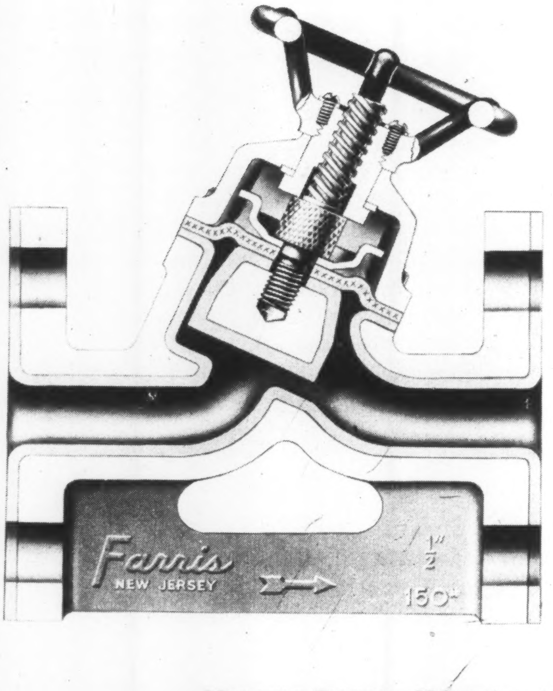


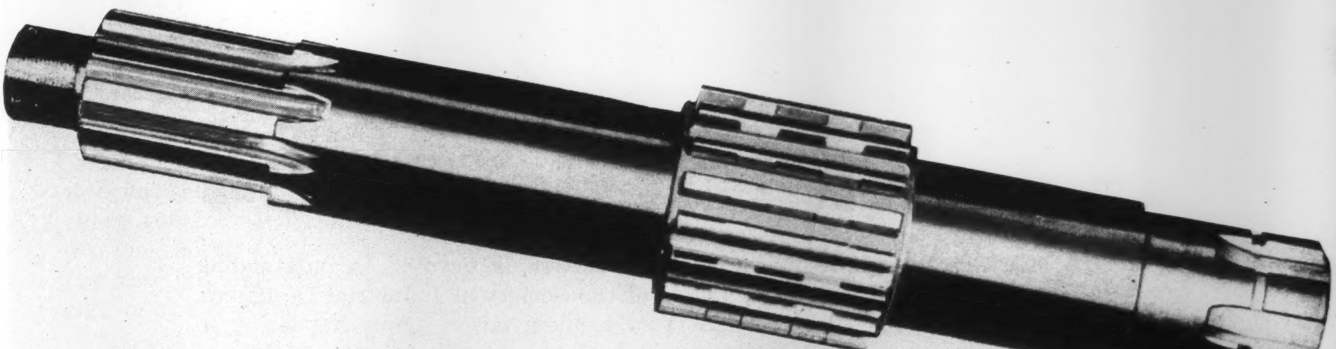
IDEA



MAGNETIC DRIVE in the new Dynapump eliminates shafts and stuffing boxes and permits dual functions of centrifugal pump and electric motor to be combined in a single-mounted unit. Essentially an ac motor with a tubular rotor, the design developed by Fostoria Pressed Steel Corp. utilizes a stainless steel cylinder in place of the conventional air gap to isolate the stator and prevent leakage of fluid into the windings. Pumping action is produced by impeller blades mounted to the rotor which is driven by the rotating magnetic field of the stator. Fluid enters at one end of the pump unit, flows through the rotor and is discharged through a diffuser section at the opposite end. Lightweight and compact, the design eliminates the need for lubrication through the use of self-lubricating graphite bearings.

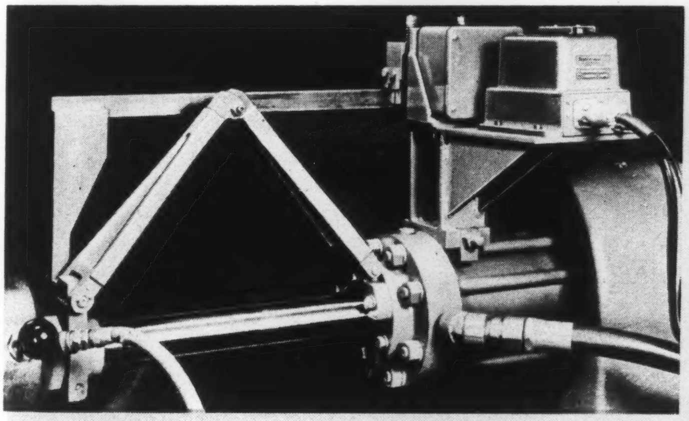
DUAL SEAL DESIGN in a valve for corrosive, abrasive or vacuum service assures positive closing and reduces maintenance. The Farris Flex Valve employs a flexible fluid-sealing diaphragm and a replaceable seating disk to eliminate packings or glands. In operation, the diaphragm acts as a seal and is not subject to wear or abrasion. A variety of plastic and elastomer materials can be adapted to the design, offering flexibility in meeting service requirements.

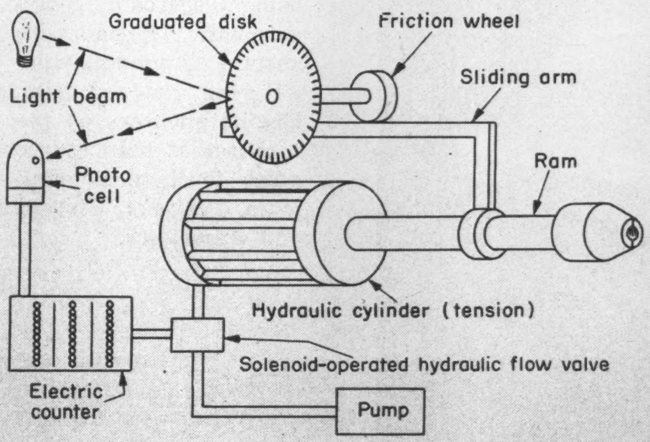




Axial locking of meshed gears to prevent creeping out of engagement under load is obtained with a clever thick-and-thin spline-tooth design. Effective under either constant or varying load, the design employs an involute tooth on which one or more sections of reduced thickness have been machined. When mating teeth are meshed, with the thick sections on one engaging the thin sections of the other, the gear members are blocked by the projecting edges from "walking" axially under load. Under no load, however, the meshing teeth may be readily shifted axially to vary the position of engagement.

The design has been applied to advantage in a transmission shaft unit developed by Rockwell Spring and Axle Co. In this unit, 17 teeth are employed with each tooth having three thin and two thick sections. Thickness of the thin sections runs from 0.008 to 0.012-inch less than that of the thick section on each side. In processing, a conventional tooth is first hobbed and the thin sections are then produced on a rack shaver.



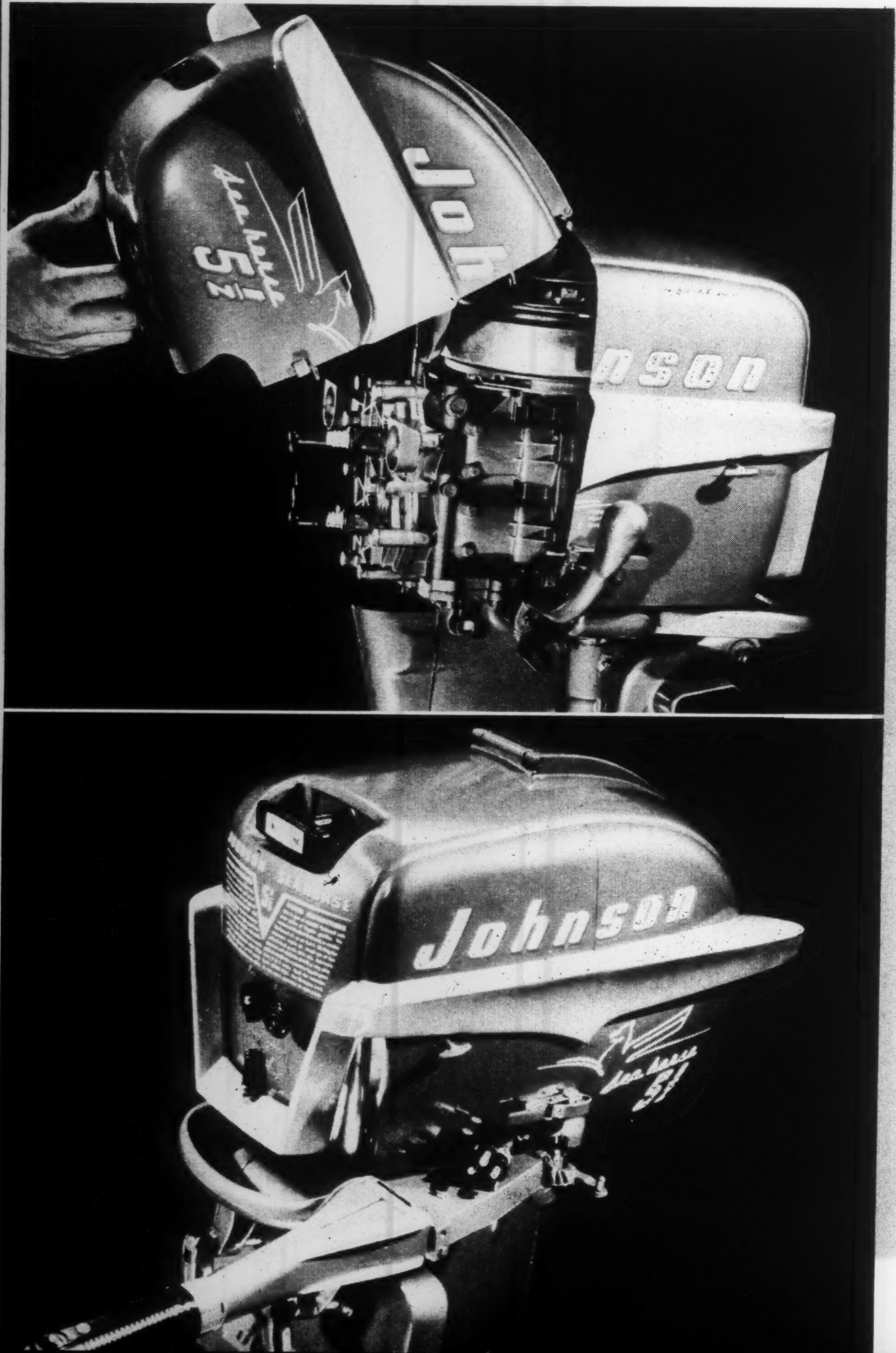


Accurate control of hydraulic or pneumatic cylinder operation under varying load is provided automatically by a system employing electronic counters. Developed by Hufford Machine Works Inc. for use on stretch-wrap forming machines the system operates independently of cylinder pressure and can be preadjusted to stop ram action after a prescribed distance has been traveled. In operation, ram motion is transmitted through a sliding arm to rotate a disk marked with a series of alternate black and white radial lines. One white line on the disk passes an aperture for each 1/10-inch of ram travel. A light beam, reflected by each white line, is picked up by a photoelectric cell and converted to an electrical impulse which is transmitted to the electronic counter. When the desired travel distance has been "counted off," the ram motion is halted. Ram travel may be readily varied by "punching" the desired distance on the electronic counter keyboard in inches and tenths.

Industrial Design, 1954

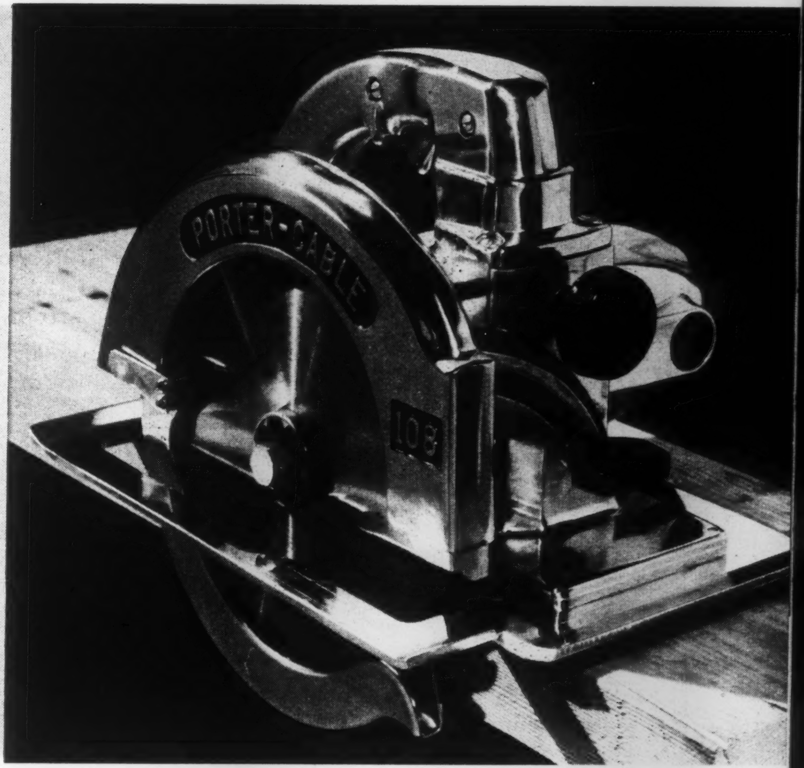
THIS MONTH the Contemporary Design section is devoted to outstanding examples of recent work of members of the Society of Industrial Designers. Machines and products were selected from a much larger group appearing in *Industrial Design in America,* 1954, published last month by the Society of Industrial Designers. Designs appearing in the S.I.D. publication were carefully screened from hundreds submitted to select the most ingenious and outstanding.

Many of these products were selected as outstanding on the basis of good appearance. However, many others merited inclusion because of redesign for better material usage, lower manufacturing cost, more convenient operation, or better product character or identification.

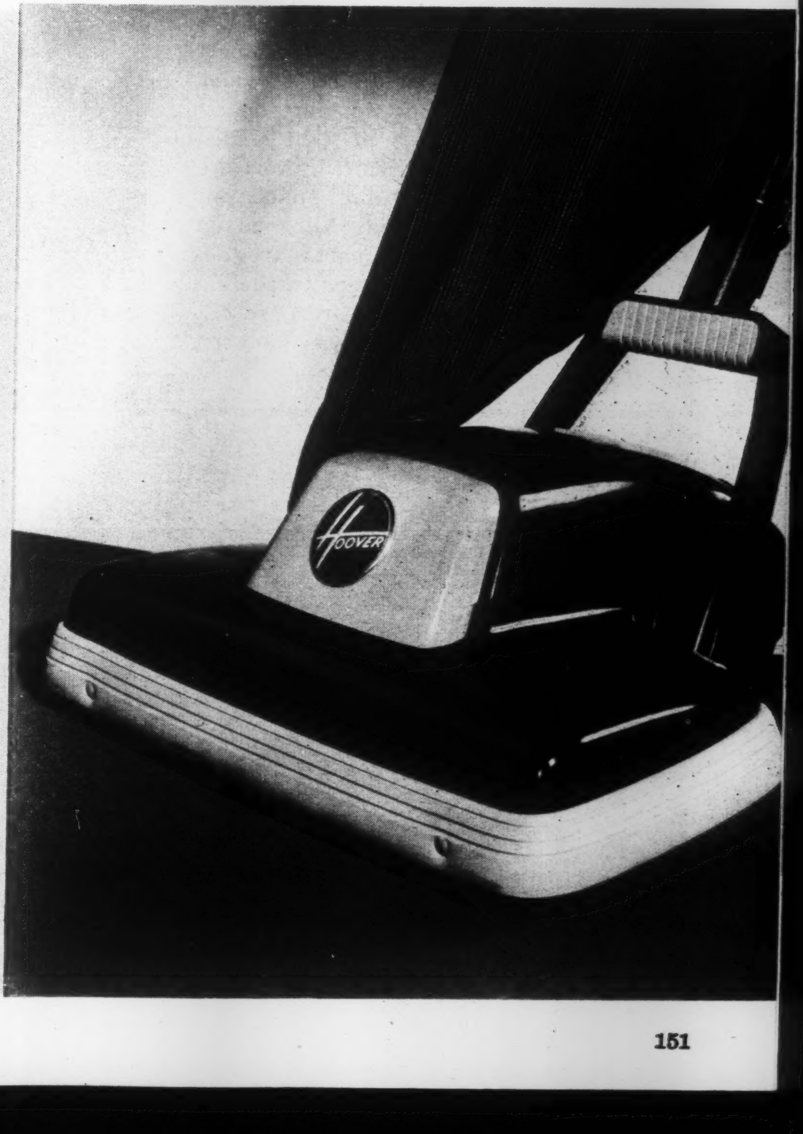


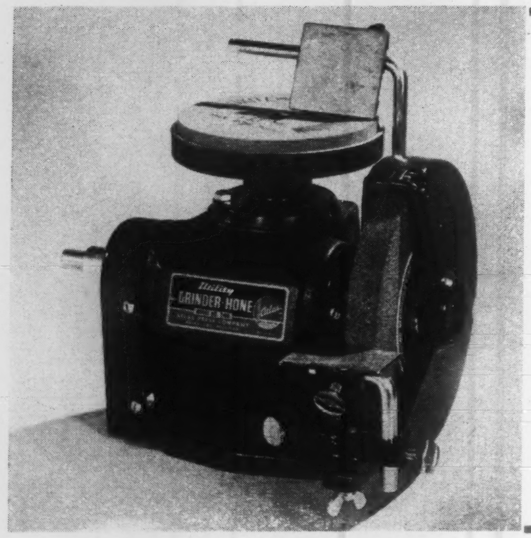
Die-cast aluminum housings contribute light weight and good appearance to Johnson's 5½-horsepower outboard motor. Quick-opening feature of the housings, said to be an innovation in outboard-motor design, is extremely useful when performing minor adjustments, cleaning spark plugs, etc. Recessed controls, pull starter and new motor rests are other functional improvements. Attractive appearance is obtained, color-wise, by using seafoam polychromatic green with natural aluminum, white lettering and red trim. Engine silencers on the carburetors help reduce noise level to a minimum. *Brooks Stevens and Associates.*

Convenience and ease of operation as well as safety were given every consideration in the design of the Porter-Cable 108, 8-inch portable circular saw. Careful design of the housing and placement of the controls and knobs resulted in a 13½-pound, easily used, well-balanced saw. A telescoping guard of improved design allows the saw to enter work smoothly, without jump. An auxiliary front blade guard reduces the number of exposed teeth, even on shallow cuts. A clutch protects operator, motor and gears in the event the saw binds in a cut. *Peter Muller-Munk Associates.*



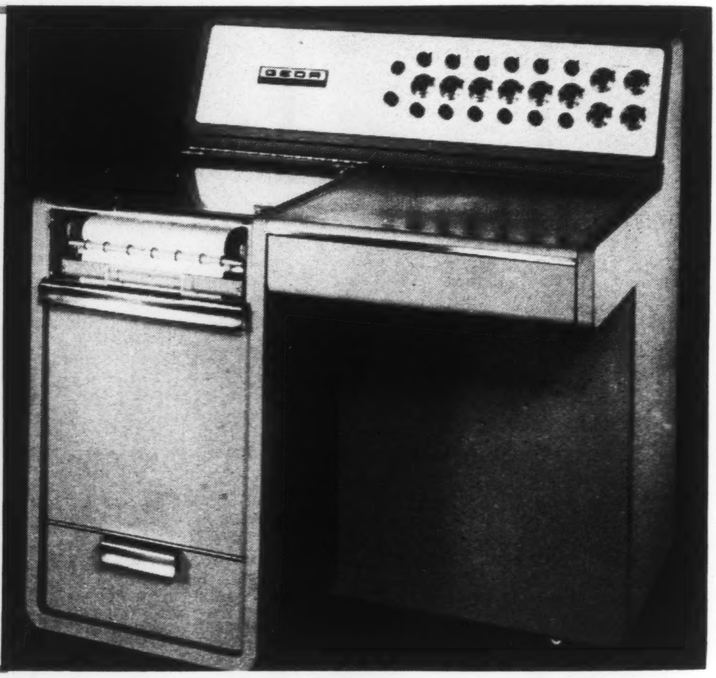
This Hoover vacuum cleaner utilizes a single die-cast cover into which the motor is inserted from the bottom. Housing contours were determined by basic requirements of nozzle width, bail clearance, switch access, etc. The main casting portion (nozzle cover) incorporates side, top and front cambers, and radii contrasts, to minimize apparent bulk while covering the required mechanism. Upper portion of the casting incorporates tapered cambered sides, cambered top and sweep-away curvatures to minimize apparent bulk and to implement the form of the lower main casting. These refinements were particularly important because only one finish could be applied to the entire cast structure. Front access cover, switch plate cover, belt guard and ball insert are made in a complementary gray color to accent the maroon housing. Circular trademark is placed on the front access cover for product identification purposes, as well as to relieve the relatively large flat area on front of the cover. *Henry Dreyfuss.*

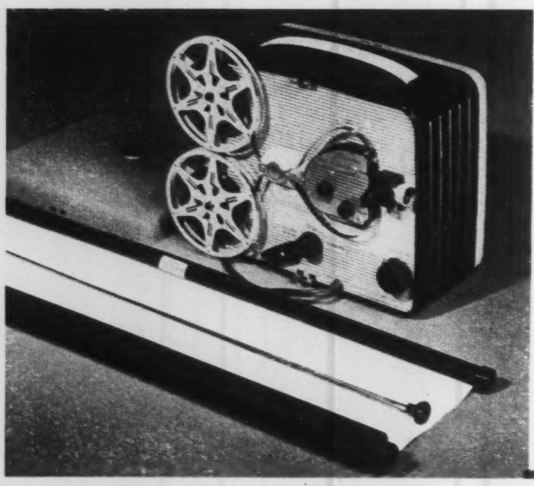




An attractively styled workshop tool, the Atlas Press Co. grinder-hone will grind, hone, clean, polish, sand or buff. For operator convenience the oilstone, a 120-320 grit sandwich type, is simply lifted from its square shaft, turned over and replaced to change grit; there is nothing to loosen. *Palma-Knapp Associates.*

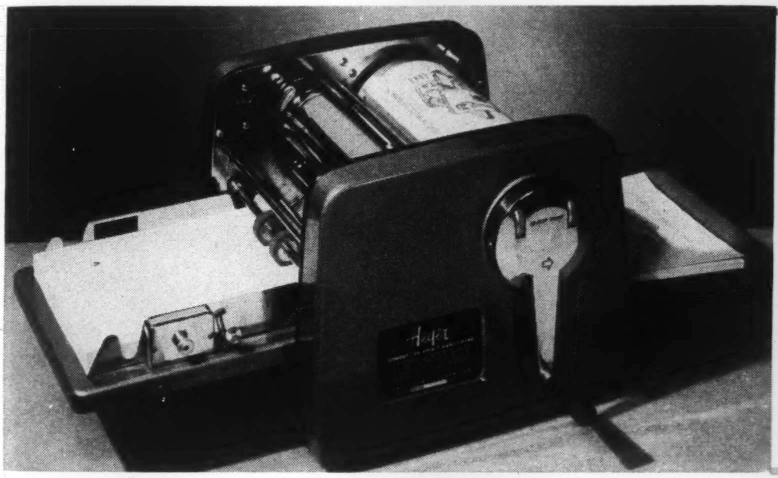
Soft gray crinkle finish and mat yellow enamels with black knobs, dials and escutcheons and accents of soft brushed aluminum hardware combine to make the R-5 GEDA six-channel recorder a pleasant piece of equipment for the operator to associate with over extended periods of time. The desk like console of the Goodyear recorder allows the operator to remain seated and provides ample storage and working space. Recording apparatus may be pulled out like a drawer, if desired. A safety catch prevents its being pulled out unless the lid is raised. All housing, chassis and external parts are designed to eliminate expensive tooling because production quantities are relatively small. *Smith and Scherr, S. I. D*





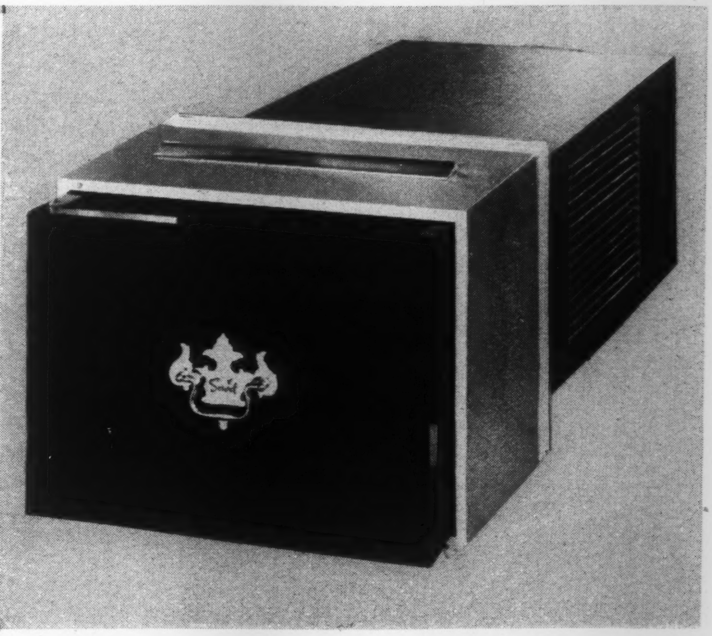
Inexpensive, and said to be the world's easiest projector to operate, Kodak's 8-mm Brownie movie projector provides a high-quality projected image. A single knob provides forward or reverse operation, stills, or rewind. An easily followed film path is printed on the plate behind sprockets to simplify threading. Indirect illumination of the sprockets allows threading in the dark. A removable side cover which can be easily snapped on or off, plus a nylon carrying handle on top of the projector, quickly convert the projector into a carrying case. *Eastman Kodak Co.*

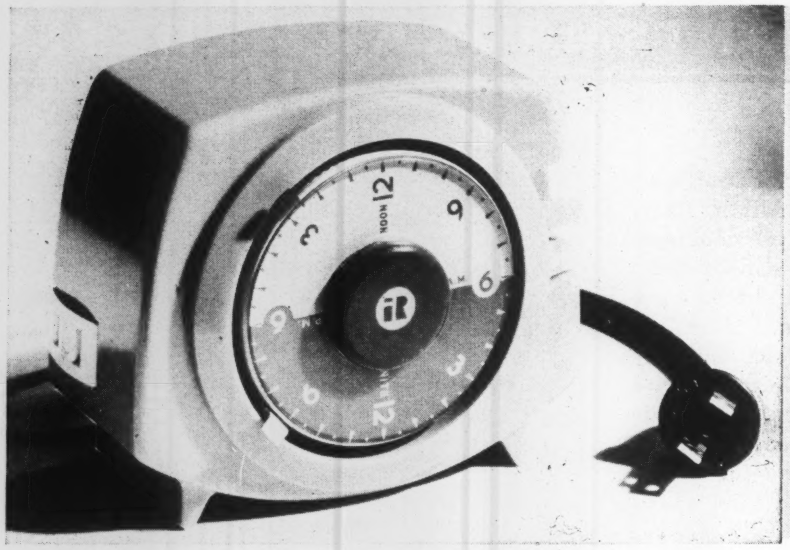
Selected by the Society of Industrial Designers for exhibit at the Trienniale Fair, Milan, Italy, were this Hotpoint washer and dryer combination. Both units are controlled by simple dials. Pushbutton-controlled fluorescent light on each unit illuminate work surfaces and inside of washer tub. Electric clothes dryer controlled by automatic thermostat and adjustable timer dries clothes in sealed chamber, requires no outside venting, and does not discharge heat, moisture or lint into laundry room. *Raymond C. Sandin, S. I. D., Hotpoint Inc.*



Case of the Heyer Corp. *Conqueror* spirit duplicator is sheet metal, finished in metallic gray Hammerloid enamel. Chromium and maroon trim are used. Operating handle is die-cast aluminum and plastic. Visible fluid supply, easy-to-read counter and automatic print centering simplify operation. *Reinecke and Associates.*

Half as wide as the usual air conditioner, this 1954 Servel model is designed to fit casement windows. Cabinet is of furniture-finished polystyrene plastic. Mahogany-colored front contrasts with blonde sides. Novel feature is the control method. Pulling out the front to one of three positions provides ventilation, cooling and ventilation, or maximum cooling. *Don Dailey, S. I. D., Servel Inc.*



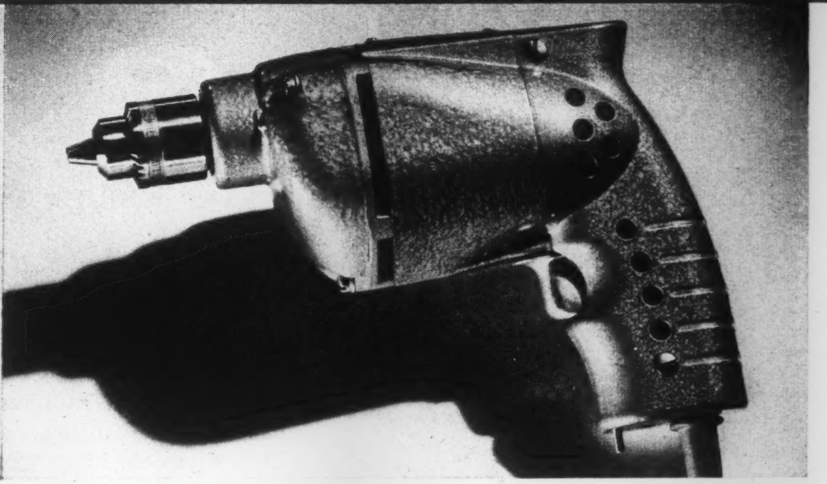


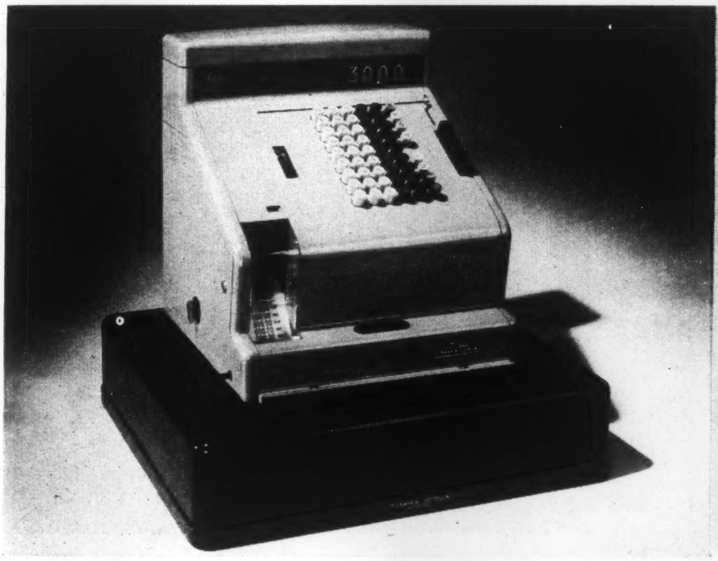
Gray Plaskon case and large legible face make the Intermatic Time-Alarm an attractive timing control for electrically operated devices. Integral feet allow it to be placed on shelf or table, and mounting holes in the back of the case permit wall mounting. Contrasting face colors eliminate the possibility of confusing morning and evening hours. *Waltman Associates.*

Staggered wheels allow contour cutting of uneven surfaces without damage to a lawn. Cost of the RPM rotary lawn mower is kept low by using aluminum die castings throughout. Appearance was improved by decorating styling of the foot treads on the housing which are used when cranking the engine. *Brooks Stevens Associates.*

Polished, plated and buffed parts of the weighing mechanism in Toledo industrial scales have traditionally been exposed to view. Skillful design eliminated polishing and plating costs and still produced an attractive mechanism by using cast decorative surface patterns and gray, blue and gold paint. Dial scroll or bezel was narrowed to permit more light to fall on graduations and figures, and to allow the dial to be read from a greater angle. Weighing head can also be revolved on the column to the best viewing position. Fabricated column encloses the loading box which was previously exposed at the end of the beams. Wheels are covered by the base skirt, permitting a larger weighing platform to be used with less floor space. *J. M. Little and Associates.*

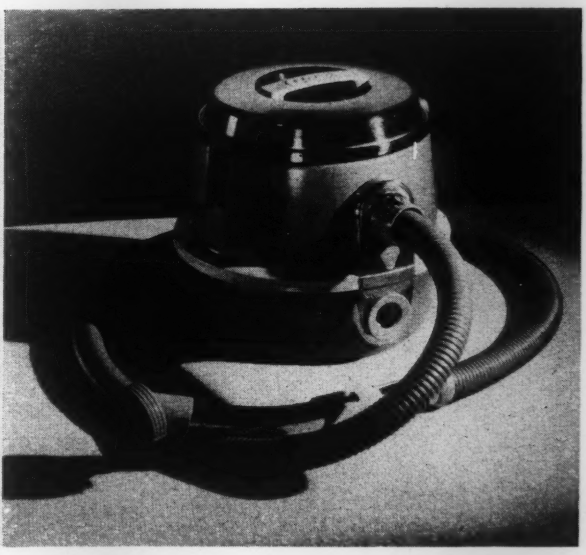
Compact, well-balanced and easily handled, the Millers Falls Co. 1/4-inch electric drill is designed to appeal to professional or hobbyist. Die-cast aluminum frame, separator and gear case, and use of self-aligning bearings, almost entirely eliminate machining. Finish is hammertone gray enamel. *L. Garth Huxtable, S. I. D.*



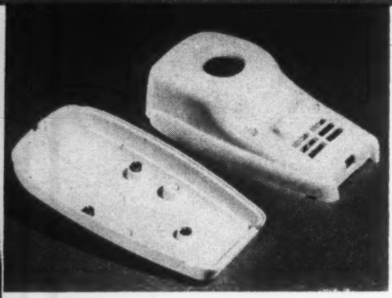


Beige, cream and brown finish of the dynamically profiled housing, shaped to the mechanism it covers, give distinction and personality to National Cash Register Co.'s Model 21 register. Base provides a hand rest for the operator when making notations about sales. *Walter Dorwin Teague Associates.*

Design features of the new Apex "Bucket" cleaner include the recessed handle to decrease apparent height; centered weight for balance and portability; large hand-size bayonet-type clamps on each side for easy removal of top for access to dust bag; and placement of intake and exhaust outlets close together with interchangeable stop to fit both openings. Chrome top offers a hard, permanent finish to maintain a constant quality surface. Waist bumper protects body of cleaner and furniture from bumps and scars, and also covers the juncture of top bag housing and bottom motor housing. It is easily removed to provide access to screws for disassembly if repairs are necessary. *Dave Chapman, S. I. D.*

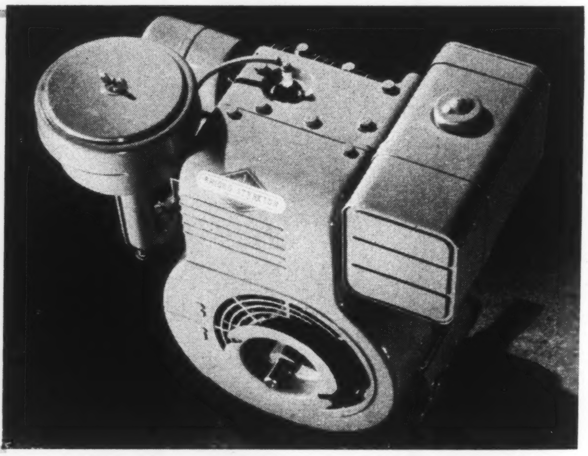


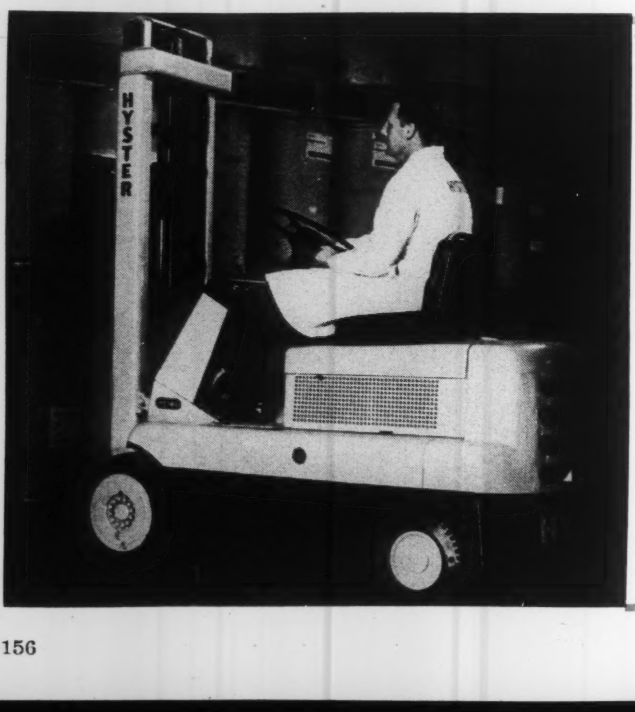
CONTEMPORARY DESIGN



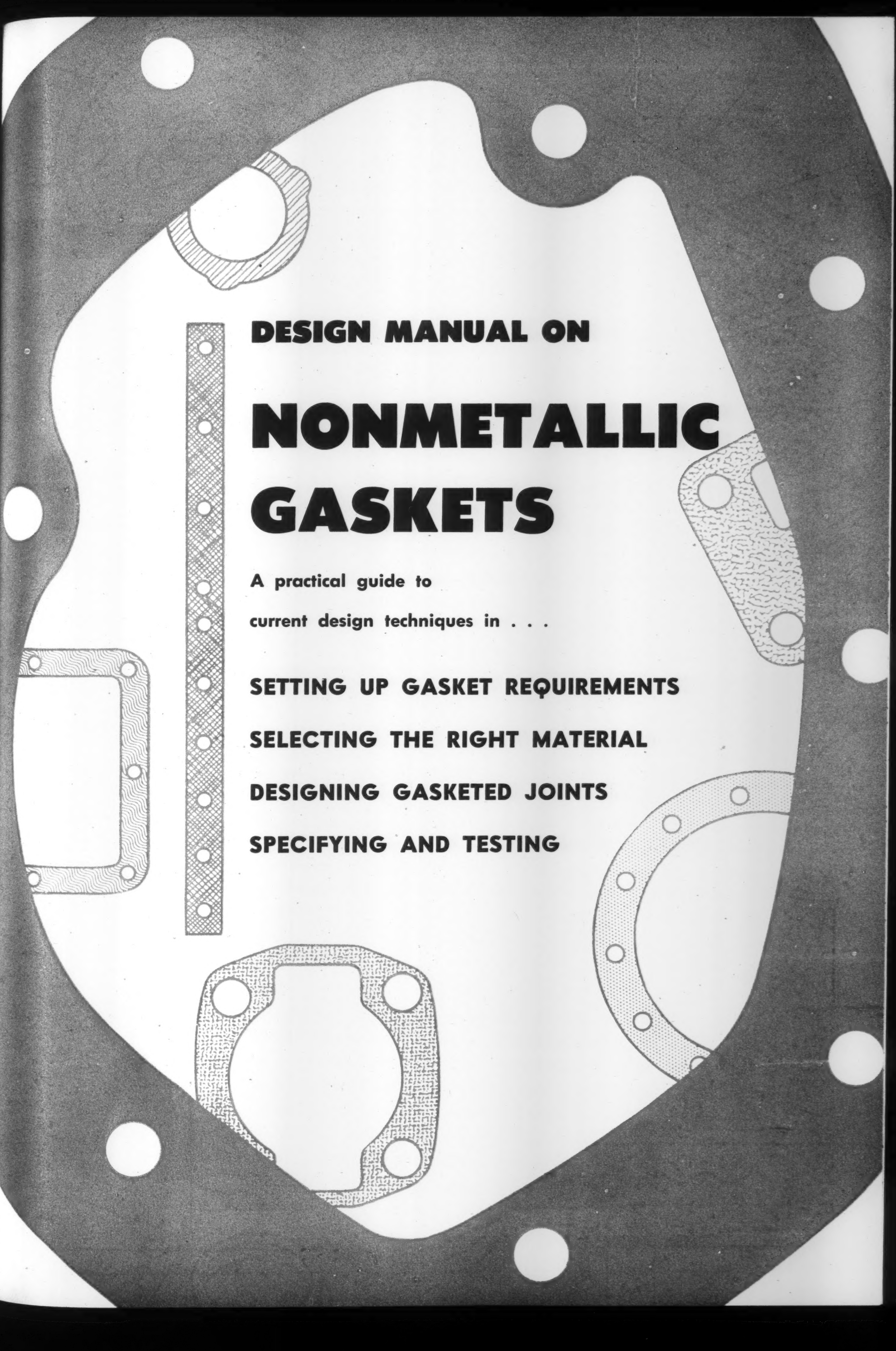
Handle and housing of G-M Laboratories Aro mixer is a two-piece cellulose-acetate molding with molded-in inserts for mounting motor and cooling fan. A coiled spring beater which mounts directly on the motor shaft can be held against the hand while running at full speed without causing discomfort or injury. Also, the beater will not snag fabrics or clothing which it may accidently contact. A simple bracket permits wall mounting, or the beater may be hand-held. *Palma-Knapp Associates.*

Visual identity has been built into the blower housing of the Briggs & Stratton engine so that it is recognizable on sight. Simple stampings for blower housing with integral grille and simplified gasoline tank results in lower costs. *Brooks Stevens Associates.*





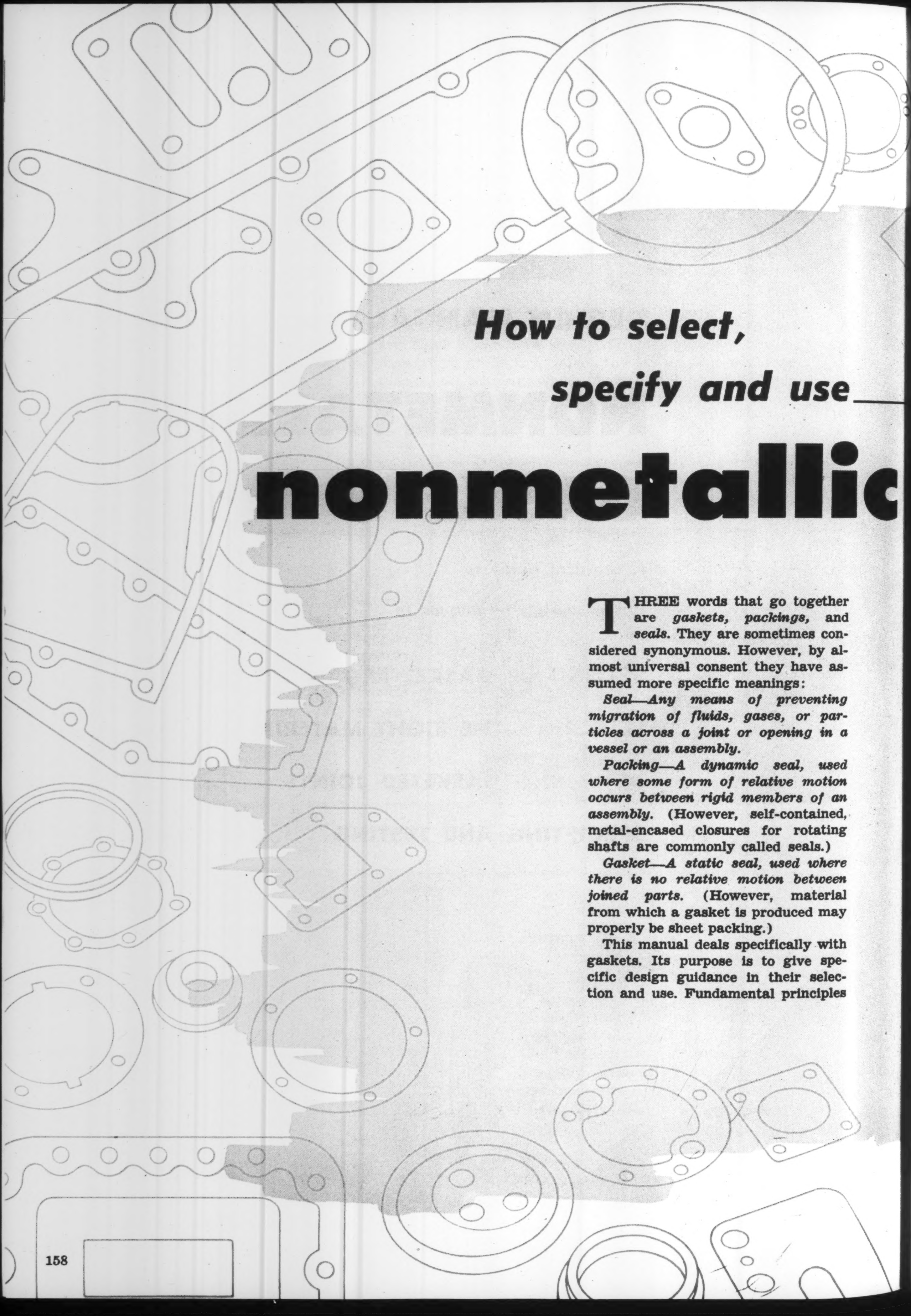
Minimum turning radius, maximum visibility, driver comfort and convenience, and power plant accessibility, as well as appearance, were all musts in the design of the Hyster lift truck. *Henry Dreyfuss.*



DESIGN MANUAL ON
NONMETALLIC GASKETS

A practical guide to
current design techniques in . . .

SETTING UP GASKET REQUIREMENTS
SELECTING THE RIGHT MATERIAL
DESIGNING GASKETED JOINTS
SPECIFYING AND TESTING



How to select, specify and use nonmetallic

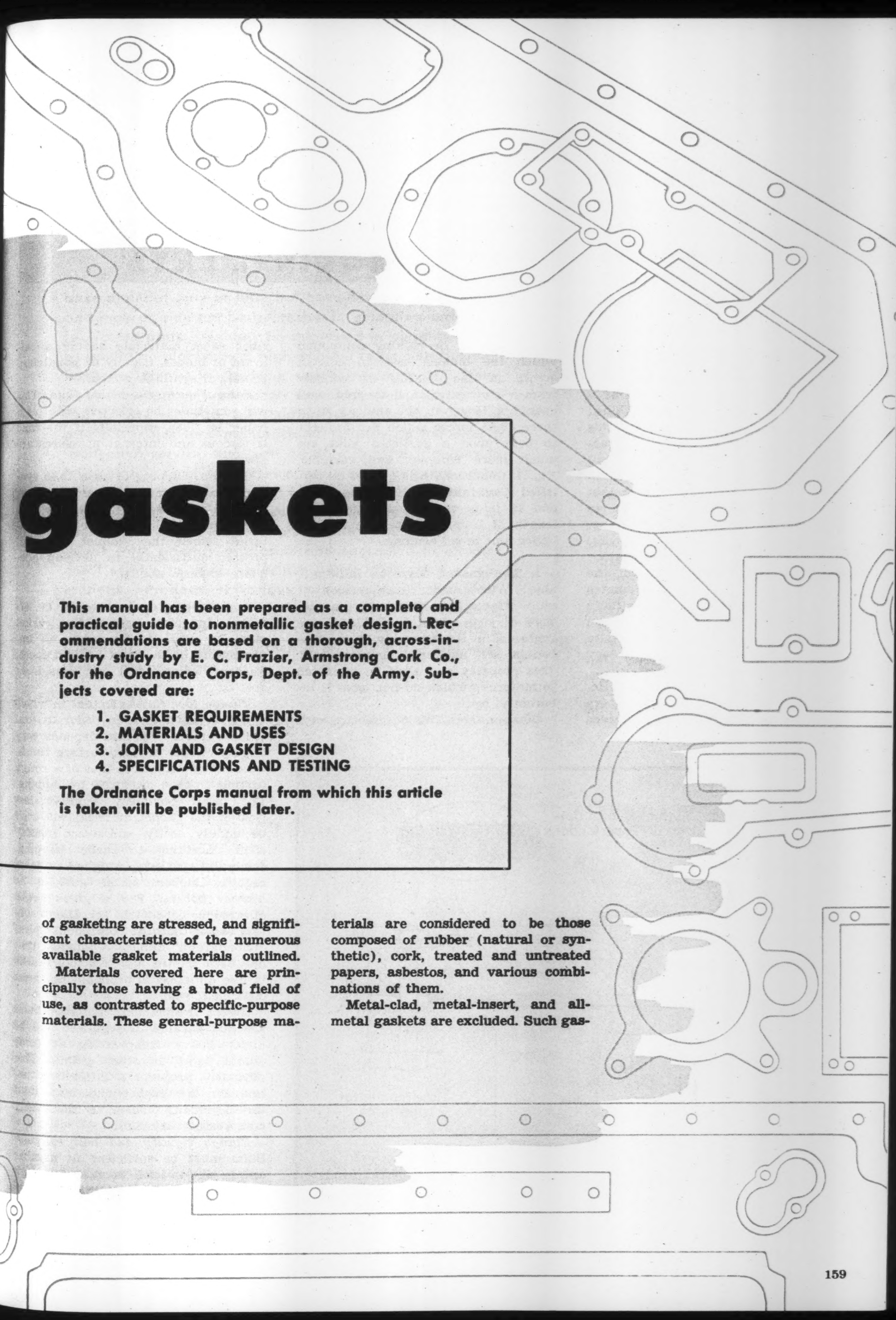
THREE words that go together are *gaskets, packings,* and *seals*. They are sometimes considered synonymous. However, by almost universal consent they have assumed more specific meanings:

Seal—Any means of preventing migration of fluids, gases, or particles across a joint or opening in a vessel or an assembly.

Packing—A dynamic seal, used where some form of relative motion occurs between rigid members of an assembly. (However, self-contained, metal-encased closures for rotating shafts are commonly called seals.)

Gasket—A static seal, used where there is no relative motion between joined parts. (However, material from which a gasket is produced may properly be sheet packing.)

This manual deals specifically with gaskets. Its purpose is to give specific design guidance in their selection and use. Fundamental principles



gaskets

This manual has been prepared as a complete and practical guide to nonmetallic gasket design. Recommendations are based on a thorough, across-industry study by E. C. Frazier, Armstrong Cork Co., for the Ordnance Corps, Dept. of the Army. Subjects covered are:

1. GASKET REQUIREMENTS
2. MATERIALS AND USES
3. JOINT AND GASKET DESIGN
4. SPECIFICATIONS AND TESTING

The Ordnance Corps manual from which this article is taken will be published later.

of gasketing are stressed, and significant characteristics of the numerous available gasket materials outlined.

Materials covered here are principally those having a broad field of use, as contrasted to specific-purpose materials. These general-purpose materials are considered to be those composed of rubber (natural or synthetic), cork, treated and untreated papers, asbestos, and various combinations of them.

Metal-clad, metal-insert, and all-metal gaskets are excluded. Such gaskets are usually employed for high pressures, high temperatures, or both. Complete engineering of such applications may present highly technical considerations which are not within the scope of this discussion.

For the most part, this discussion also excludes packings. An exception is O-rings. Since O-rings may perform the functions of ordinary flat gaskets as well as those of shaft or piston packings, they have been accorded treatment comparable to that given other gaskets.

Molded parts produced from rubber and plastics are very often called upon to perform a gasketing function. This manual stresses these functions without going into details of composition, parts design and molding.

GASKET REQUIREMENTS

A GASKET creates and maintains a tight seal between separable members of a mechanical assembly. A seal may be obtained without a gasket by perfect mating of machined or ground surfaces. However, this method is almost sure to be impractical except possibly for some small and very exacting assemblies in which cost is secondary to certain performance requirements. Even in such an assembly, rough handling, or corrosion or warping in service, may spoil the initial perfect mating and thus defeat the purpose of the design. Hence, the gasket promotes economy of effecting a seal initially and prolongs the useful life of an assembly. The gasket itself is usually inexpensive and lends itself to easy replacement.

In compensating for errors and irregularities in joined rigid members of an assembly, the gasket serves like the putty or calking compound which the builder uses to correct errors in the mating of window frames and exterior household wall openings. However, the analogy stops there since forces which are brought to bear upon a gasketed joint are much more complex and variable, *Fig.* 1. Conditions which must be satisfied if an initial seal is to be made, and if it is to last a satisfactory length of time, may be summarized under four broad headings:

1. The gasket must be impermeable. When under compression it must offer a true barrier to the passage of such gases or fluids as are contained in the assembly. Some materials are inherently impermeable. This property can often be imparted to materials which do not have it inherently, by:

Compression: This is effective with fiber sheet materials having a saturant or binder, usually of plasticized protein or synthetic rubber.

Saturation by the sealed fluid: This will sometimes be effective with plain paper or fiber, especially if the fluid is viscous and internal pressures are low.

Coating: Dipping of gaskets in synthetic rubber latex or cement, glue, or resin may be rather effective with cork composition and fiber sheet materials when they cannot be compressed sufficiently to develop adequate impermeability.

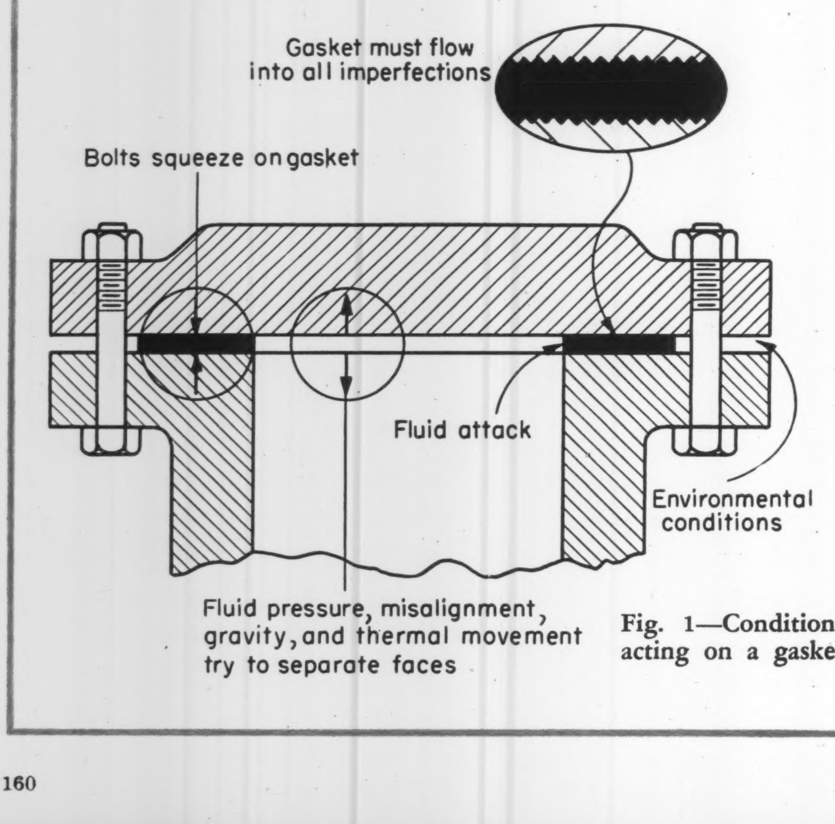


Fig. 1—Conditions acting on a gasket

2. Complete contact must be effected. In some manner the gasket must be made to flow into all imperfections of the joint contact faces. Factors which must be considered are:

Flange face finish: Extent to which a gasket must flow in order to present an impervious seal depends very largely on the contact surface finish, which may vary from that of a rough casting to that produced by lapping. The latter obviously requires less flow of the gasket material, but may be unduly costly and exert insufficient resistance to gasket slipping. Generally speaking, rougher surfaces require thicker, softer gaskets—or heavier bolting. For a given depth of groove, concentric serrations will seal easier than the continuous spiral "phonograph" finish. A surface that has been planed and has tool marks in one direction is probably the most difficult to seal.

Errors of alignment: If flange faces are not parallel, the gasket will be under heavy compression at some points, light at other points. This obviously presents a difficult situation for the gasket and may limit the designer's choice to the easily compressed materials.

Flange rigidity and bolt spacing: Bolts must be sufficient in number and in size to load the gasket enough to flow it into irregularities. A beam effect is created between bolts and more or less bowing occurs depending upon flange material and thick-

On the gasket industry . . .

An outline of the trade channels through which gaskets can be obtained may be of interest. In general, gaskets are obtained in production lots from two sources:

Primary producers or processors: **Gaskets generally start out as sheets, rolls or blocks of manufactured or processed material. The manufacturer or processor of the base material may or may not have fabricating facilities, and may or may not be interested in accepting orders for fabricated parts. He may be interested in quantity orders as would be placed by a high-volume consumer; but may have no interest in servicing small requirements. However, these primary producers are likely to be best qualified to give technical information regarding the types of products which they manufacture. If they do not offer a fabrication service, they will be able to refer inquiries to fabricators. Most producers operate on a national scale.**

Fabricators: **Fabricators in the gasket business, also called gasket cutters, are usually independent local businesses of small or medium size. They buy sheet or roll goods from primary producers and specialize in offering quick service to those industries within their area of operations. Products of various gasket material manufacturers are generally stocked. Small orders can be handled to advantage, and deliveries can often be made with a speed which cannot be matched by any major producer from a distant plant.**

ness. The designer must consider whether to use numerous light bolts closely spaced or fewer and larger bolts.

Keeping gasket positioned: If the gasket "walks out" of the joint, firm contact cannot be made. A high coefficient of friction or rough flange finish may be all that is necessary to avoid this condition. However, some applications may require mechanical confining and positioning means, such as grooves.

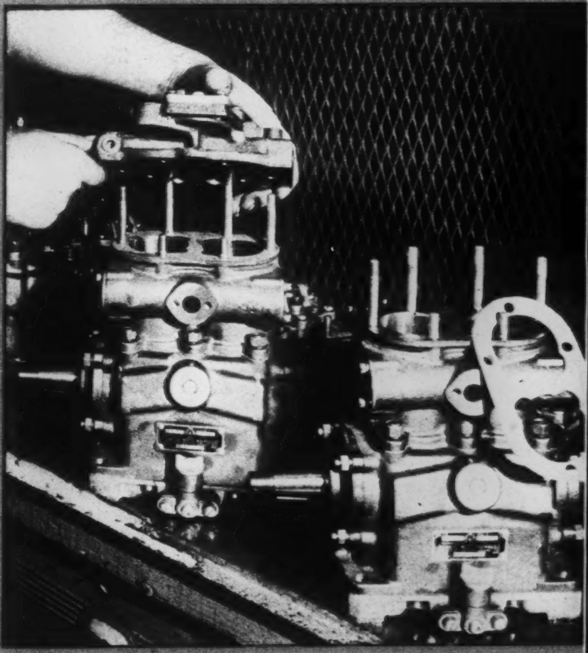
Gasket surface treatments: A thin coating of synthetic rubber on both sides of a hard fiber gasket flows easily into flange surface irregularities. Usually about 0.001-inch thick, this coating performs a different function than one applied to develop impermeability, and may be applied to the sheets before the gaskets are cut.

3. Complete contact must be maintained. Many gasketed joints are subject to considerable movement with changes of temperature and pressure, vibration and mechanical strain. Ability of the gasket to follow all of these possible movements, and maintain thorough contact with the flanges, is determined by:

Elastic response of gasket: In low-modulus materials used in low-pressure, moderate-temperature joints, this is usually the prime factor in maintaining a seal.

Edge effect of sealed fluid on gasket: Choice of a gasket which swells moderately in contact with the sealed fluid aids in assuring continued tightness of a joint. Conversely, a gasket which is not affected, or which shrinks at the exposed edge, may permit early failure of the joint. Principal precaution in taking advantage of this edge effect is to avoid a gasket-fluid combination which will lead to actual dissolving or extreme deterioration of the gasket, or harmful contamination of the fluid.

Elasticity of bolts and flanges: This factor must be relied upon for continuous tightness in high pressure, heavy-duty joints employing low-compressibility, high-modulus gaskets. In such joints the bolts are the resilient members relative to the joined members. The forces involved call for careful design and control through proper use of available aids to de-



Air Compressor

Fiber is used as the gasketing material on cylinder heads of small Bendix - Westinghouse air compressors.

sign and assembly, such as the ASME *Unfired Pressure Vessel Code* covering design calculations, and the use of torque wrenches to help insure proper pull-up.

Adhesion of gasket to flanges: Gaskets of rubber, cork, and to some extent other materials, tend to adhere to flanges with time. Once this has occurred, worries regarding maintenance of gasket pressures are largely eliminated, since a strongly adherent gasket will hold quite high fluid pressures with very low residual flange pressures, and in the face of joint movements of considerable magnitude. Rubber cements and other adhesives may be deliberately employed to make adhesion more immediate and certain. However, an adherent gasket—regardless of how the adherence is effected—causes difficulty of separation. For this reason, many gaskets are treated with graphite or mica to inhibit the tendency to adhere.

4. The gasket must be compatible with its environment. A mutually agreeable relationship between the gasket and the conditions which bound it on all sides rests upon:

Temperature response: Composition of the gasket should be such that it will withstand the full range of temperatures for which the device or system has been designed. Gasket behavior at high temperatures is better understood than at extreme low temperatures, and the useful limits more accurately defined. Sustained high temperature causes accelerated aging of many materials and encourages creep or stress relaxation, in metallic as well as nonmetallic members of a gasketed joint. Extreme low temperature causes sluggishness and brittleness in most gasket stocks, and flexing may be possible only in the case of materials compounded for the condition. Gasket materials in general have a somewhat higher coefficient of thermal expansion than most of the metals from which flanges and bolts are made. In certain situations involving wide and rapid temperature fluctuations, this factor of relative expansion and contraction due to such temperature changes may require special design consideration.

Chemical inertness: Reaction between the gasket and the sealed substance may be highly beneficial if it shows up as moderate swell. Otherwise it can lead to destruction of the gasket and contamination of the material being handled. Also, staining and corrosion of flanges and nearby polished reflectors and contact points may occur.

Resistance to miscellaneous hazards: Ultraviolet light, vermin, ozone, salt spray, fungi, vibration, shock and general aging—these are some of the other environmental conditions that may challenge the resourcefulness of the design engineer.

Selection of a material for any gasket application hinges upon how well, and by what means, the proposed material can be made to meet these four basic requirements. Hence, these four requirements constitute a convenient basis for discussion and evaluation of the characteristics of the gasket materials reviewed in later sections.

From the foregoing, there is obviously no universal answer. For the most part, the designer "plays by ear" and is constantly having to check his calculations and reasoning against field experience. Every gasket material seems to find places in which it alone does an outstanding job; but no single material does an outstanding job in all kinds of applications. Therefore, the designer must examine materials' characteristics in relation to application demands.

GASKET MATERIALS AND USES

THERE are innumerable types, classes, styles and grades of gasket materials. New products and modifications of old products are introduced with astonishing frequency. Fortunately, nearly all materials can be grouped with others of like composition or properties:

1. Asbestos products
2. Cork-and-rubber
3. Cork composition
4. Rubber and plastics
5. Paper
6. Leather
7. Composite and miscellaneous gaskets

Properties and uses of each type are summarized in *Table* 1. Also of interest are treatments and coatings for gaskets, which will be covered.

Asbestos Products

Two types of asbestos fiber are important for gasket manufacture:

1. *Chrysotile:* This is common white asbestos. It is a mineral consisting essentially of magnesium silicate combined with approximately 14 per cent water of crystallization. It has little resistance in itself to the action of strong mineral acids, but may be used with weak acids and with most alkali solutions. When processed with binders such as rubber, the resistance of the resulting composition to corrosive agents and to temperature is determined by the nature of both the asbestos and the binder.
2. *Crocidolite:* More commonly known as blue asbestos, this material is a sodium-iron-silicate complex. It is chiefly used in the manufacture of acid-resistant gaskets.

Asbestos fibers have certain basic attributes which make them valuable for gasketing. They also have limitations, but since these vary considerably with the form in which the fibers are used, limitations will be discussed more specifically under the various product subdivisions. Properties which make asbestos a valuable gasket material are:

Heat resistance: Asbestos fibers retain most of their inherent strength up to about 750 F. Above that temperature, they tend to lose their water of crystallization, a process which becomes almost instantaneous at about 1300 F. Asbestos from which water of crystallization has been driven may be reduced to powder by slight rubbing. In practice, asbestos is seldom used alone or in its pure form and, therefore, actual heat resistance of products made with asbestos will be determined by heat resistance of all elements of the product.

Resistance to shear and compression: Asbestos gaskets and compositions in which asbestos fibers are used as fillers are usually excellent in their resistance to crushing loads and to the cutting action of narrow and sharp-edged flanges.

Dimensional stability: Being little affected by humidity changes, asbestos materials are quite stable dimensionally.

Ability to be combined with other products: Implications of necessity as well as virtue are involved here, because pure asbestos products are very low in strength and high in porosity. For this reason, asbestos is almost always used with other products. It may be processed with metallic or cellulose fibers for strengthening; with binders and saturants for greater imperviousness; and it proves a good mixer when added as a filler to rubber and plastic compounds.

Principal Asbestos Materials: Main types of asbestos gasket materials are:

Rubber-asbestos compositions: This includes "compressed asbestos" and several other forms of asbestos sheeting or composition in which the physical properties and general fields of application of compressed asbestos are duplicated quite closely. This is by far the most important classification commercially, as well as from the standpoint of varied application possibilities.

Woven and braided asbestos: Fibers may be processed into cloth and other special forms, softer than the compressed sheets and susceptible to saturation with special treatments.

Millboard and paper: These materials are relatively pure forms of asbestos fiber, bonded perhaps with starch or sulphites.

Rubber-Asbestos Compositions: Rubber-asbestos sheets vary somewhat in appearance according to the formula and process of manufacture, and whether pigmentation or some external after-treatment has been employed. The specific form known in the trade as compressed asbestos is made by calendering a dough of asbestos fibers and rubber cement. It has a pronounced grain effect, and close examination will usually reveal clumps of undispersed asbestos fibers. The resulting product is characteristically rather hard and unyielding. It is also tough and stable dimensionally.

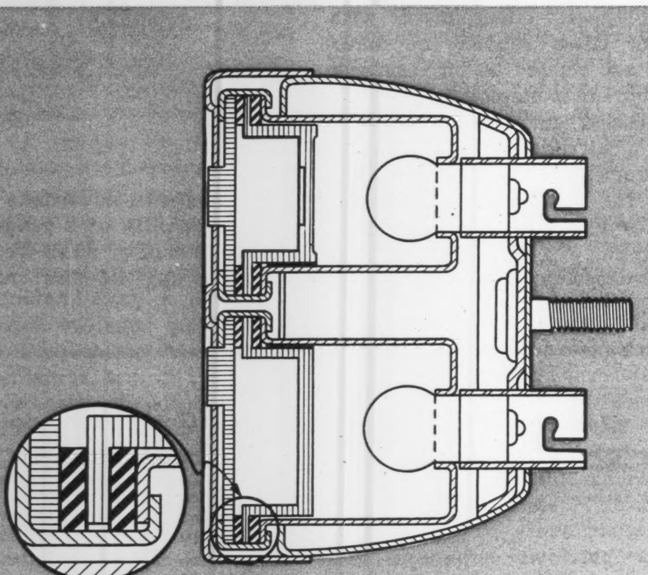
Several other methods of manufacture, including latex treatment of asbestos paper or impregnation of asbestos felt with a rubber solution, provide gasket materials having similar characteristics, although less hard and more resilient. Treatment of asbestos fibers with rubber latex prior to forming the sheet, a process commonly known as beater saturation, is a comparatively recent development which offers further advantages of a more homogeneous, nondirectional product of greater flexibility and resilience.

Compositions of rubber and asbestos may be made with natural rubber or with practically any of the synthetic types. When made with natural or GR-S rubber, the materials are not classed as oil resistant. When neoprene is employed, the product is classed as oil-resistant; and the use of nitrile rubber makes for still greater oil and aromatic fuel resistance. The rubber binder typically constitutes 10 to 25 per cent of the total weight.

Rubber-asbestos composition sheets are furnished in various grades, with the possibility of a range in price of 100 per cent or more from the lowest to the highest-cost material. This

Table 1—Properties and Uses of Gasket Materials

Classification	Special Characteristics	General Uses
Compressed Asbestos	Tough and durable. Dimensionally stable. Relatively incompressible. Good steam and hot water resistance. Oil and solvent resistance determined by characteristics of rubber binder.	Heavy-duty bolted and threaded joints, as in water and steam pipe fittings, manifold connections. Temperatures to 500 F.
Cork-and-Rubber	Provides fluid barrier and resilience with compressibility. Properties of flow versus compression subject to controlled variation. Lower tensile and elongation properties than rubber. Chemical properties about same as base polymers. Higher in cost than cork composition or fiber types, but lower than straight rubbers. Does not extrude from joint. Die cuts well. High coefficient of friction.	General-purpose gasketing, except steam lines, combustion chambers, etc. Enables design of metal-to-metal joints with gasket positioned in channel or counterbore, with no allowance for flow. High friction keeps gasket positioned even where closing pressure is not perpendicular to flange faces.
Cork Composition	General-purpose material. Variable as to binder, texture and hardness (density). Compressible. High friction whether dry, wet or oily. Low cost. Excellent oil and solvent resistance. Poor resistance to alkalies and corrosive acids.	Mating rough or irregular parts, as glass, light stampings, unfinished castings. Oil sealing at low cost in normal range of temperatures and pressures.
Rubber, Plastics	Highly adjustable according to compounding, hardness, modulus, fabric reinforcement, etc. Generally impervious. Not compressible.	Installations involving stretching over projections, or where flow of gasket into threads or recesses is desired. For lowest compression set and maximum resistance to fluids such as alkalies, hot water and certain acids. Ability to be molded permits use for special design and assembly conditions.
Paper:		
Untreated	Low in cost; noncorrosive.	Spacers, dust barriers, splash seals, where breathing and wicking not objectionable.
Treated	General-purpose material having better tensile strength than cork composition, but less compressibility. Good oil, gasoline and water resistance, but alternate wet and dry cycles may cause shrinkage and hardening of some types.	Machined or reasonably uniform flanges where adequate bolt pressures can be applied. Relative firmness and high tensile strength permit use of thin gaskets to give good alignment of covers and connected parts.
Leather	Tough; porous; abrasion-resistant; flexible at extreme low temperatures. Tanning and impregnation are important variables. Can be molded to simple shapes—cups, V's, U's.	Widely used in dynamic packing applications and as back-up for rubber O-rings in high-pressure joints. Avoid steam, acids, alkalies.
Combination Constructions	Innumerable modifications available, depending on materials used and methods of combining.	Usually employed for extreme conditions and special purposes.



Automotive Taillight

Gaskets for these automotive taillight lenses must be soft and highly compressible to compensate for irregularities in the plastic lens and stamped metal case. A sponged neoprene rubber-and-cork composition provides a weatherproof dust-tight seal and cushions the lens flange to prevent breakage during assembly of the lamp unit.

price differential is due to varying costs of the different types of rubbers used and also to the amount of mineral fillers employed. Care must be exercised in the selection of the proper grade for the job at hand.

FORMS AVAILABLE: Rubber-asbestos materials are almost invariably furnished in sheets, in rolls, or as die-cut parts. Standard types of compressed asbestos are formed on cylinders, from which they are stripped as 120 by 120 or 150 by 150-inch sheets. They are sold in these sizes or, more frequently, are cut to smaller segments, such as 40 by 40 or 50 by 50 inches. Those products available in continuous roll form are generally 24 inches or greater in width and are packaged in standard units such as 25 or 50 square yards. Usual thicknesses are $\frac{1}{32}$ and $\frac{1}{16}$-inch, although here again considerable choice is possible, with $\frac{1}{64}$-inch generally specified as the minimum. Maximum thickness is limited only by the practical considerations of good design and means of laminating and fabricating. It is difficult to conceive of any gasket application requiring a thickness in excess of ¼-inch.

COST FACTORS: Some manufacturers of rubber-asbestos composition sheets sell their product by the pound, while others price by the square yard. Since weights are likely to range from 3½ to 10 pounds or more per square yard in the $\frac{1}{16}$-inch thickness, it is essential to have a basis of converting from weight to area in order to make a proper comparison of competitive offerings.

Most grades are of intermediate cost compared with other materials; that is, they are more expensive than cork composition or vegetable fiber but generally less expensive than straight synthetic rubbers, resins, or plastics. Fabrication is almost always from sheets. Parts will usually be priced according to over-all size, subject in some cases to center allowances.

PROPERTIES AND LIMITATIONS: Compressed asbestos and other materials grouped with it form a versatile link between the so-called soft gaskets and the hard metallic or semimetallic types. They rate as follows when measured by the yardsticks outlined in the previous section:

Impermeability: Compressed asbestos is best used where bolting pressures are rather high, and under these conditions, there is sufficient compacting of the structure to make the material impermeable. Without high bolting stress, however, the clumps or pencils of undispersed asbestos may offer some conduction of the sealed fluids.

Achieving complete contact between gasket and flanges: Compared with more yielding gasket materials, compressed asbestos requires a relatively heavy load to achieve intimate contact with flange faces. There is a threshold pressure to which such a gasket must be subjected in order to achieve completeness of seating to hold even very light or atmospheric pressures. While this threshold pressure varies according to the flange finish, rigidity, bolt spacing, and the characteristics of the particular type of rubber-asbestos under consideration, it is likely to be in the order of 1500 psi on the area of the gasket. From this fact it is evident that the place for compressed asbestos is in relatively heavy, rugged constructions employing rigid flanges and adequate bolting capacity.

Maintenance of complete contact of gasket to flanges: Compressed asbestos has little elasticity. It does not have within itself those properties which cause a gasket to follow flange movements. How then does it keep on sealing heavy-duty flanges? Having so little compressibility, it forms a rather solid, inert filler between the flanges. Thus, after the bolts have been pulled up to the point where the gasket is well seated and has conformed to the irregularities of finish and alignment in the joint, it is scarcely more yielding than the metal components themselves. Continued tightening of the bolts then causes them to stretch.

Elasticity of these stressed bolts really provides the mechanism by which tightness of contact is maintained. In time, and particularly if high temperatures are encountered, sufficient creep will occur within the structure of the gasket and also within the bolts to permit a phenomenon variously described as stress relaxation, creep, cold flow, or stress decay. In other words, in time the bolts tend to become loose, and may need tightening. Compressed-asbestos gaskets are not notorious for adhering to flanges, but treatments, as with graphite, are often employed to prevent adhesion. If occasional or frequent separability of the joint is not contemplated, good results may be obtained by permitting adhesion to occur. Once this has happened, there is little likelihood of leakage occurring at the joint.

Compatibility between gasket and its environment: Chemical properties of compressed asbestos are largely the result of the type of rubber with which it is compounded. Asbestos fibers are inherently more resistant to most chemicals than are cellulose fibers and, therefore, compressed asbestos is likely to be chosen over plant fiber types where acidic or alkaline conditions are encountered. However, in chemical processing especially, chemical resistance of asbestos may have to be examined in relation to the probability of contact with materials such as nitric acid.

Temperature resistance of compressed asbestos is a matter of varying opinion. Some do not care to use it much above 250 F, but most authorities regard 500 F as a conservative limit. There are those who say that the material can be used at 750 or even 850 F, but considerable caution is recommended when considering a product for such temperatures. Much depends upon what is expected of the gasket; that is, what is regarded as acceptable performance.

TYPICAL USES: As pointed out previously, rubber-asbestos is best used in relatively heavy flanges in which adequate bolt pressure is provided; where machining irregularities are not excessive; and where flanges are flat and rigid. These factors, together with its ability to stand temperatures as high as 500 F, make the material particularly valuable for the general run of pipe-flange applications such as encountered in oil refineries and chemical processing plants. It is considered satisfactory for either high or low-pressure water joints and in many oil and gasoline services, although this is contingent partly on the type of rubber with which the material has been compounded. It gives excellent service in contact with most ordinary industrial fluids, such as alcohol, glycerine, caustic solutions, and weak acids.

Because it is a highly stable material showing little response to changes in humidity and temperature, rubber-asbestos finds its way into many applications where plant fiber or other materials would perhaps seal more effectively or at lower flange pressures but which impose conditions tending to cause shrinkage or drying out of other fiber types. Some of the newer types of plant-fiber gasketing materials with nonextractable saturants may replace asbestos in many of these low-temperature, low-pressure applications requiring mainly that the gasket remain stable in dimensions and properties over a long period of time.

Woven and Braided Asbestos: Asbestos fibers may be spun into yarn, and the yarn woven into fabric or braided into various rope-like formations. For added strength without sacrifice of high temperature resistance, the yarn may be reinforced with metallic wire or strands. Cotton may also be used for reinforcement, but lowers the heat resistance. Braided styles are frequently impregnated with a lubricant and graphite treatment. Woven fabrics may be used plain, or may be frictioned with rubber, or saturated with latex or resin. Both blue and white asbestos fibers may be worked up into the forms described, although the blue asbestos is generally reserved for certain difficult acid applications.

FORMS AND USES: Braided materials are used for packing in stuffing boxes on reciprocating and rotating members to prevent leakage of water, oil, steam, etc. For these purposes, they are furnished either in the form of coils or split-wall rings. Woven fabrics may be die cut to various sizes and shapes, but the fabric is more likely to be rubber treated and folded and pressed to make rings, ovals, squares, and other shapes as required for applications like tube plates of boilers. Tape, also made from folded cloth, is used for gasketing of steam cylinder heads, heater doors, and other power-plant applications. Asbestos fabric is also formed into continuous-length tubular gasketing and used for steam service, hand holes, manholes, heater doors, etc. Most types of woven and braided asbestos packing and gasketing materials as described above are "catalog" items offered by numerous supply distributors for power plant and factory maintenance. They are not generally associated with factory-assembled, mass-produced items, but there is no reason why they cannot be so used if they happen to fill a particular need better than some of the more commonly used products.

Millboard and Paper: Little more needs be said regarding this type. In gasket manufacturing, the principal use for asbestos millboard and paper is as soft fillers for metal-jacketed or other reinforced constructions. Automotive cylinder-head gaskets are one of the most important uses.

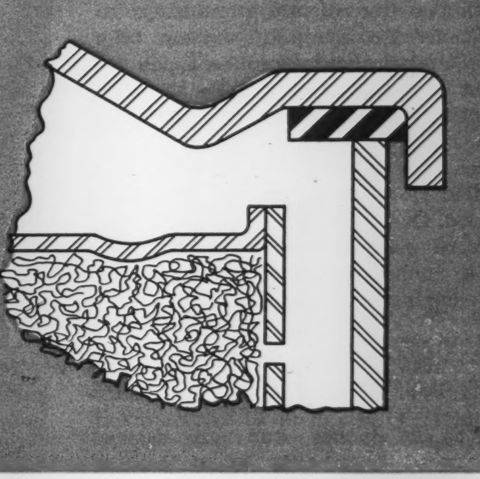
Cork-and-Rubber

Cork and rubber are materials of very different attributes. Cork is compressible; application of a load causes a reduction in volume with negligible flow. Its response to pressure is essentially pneumatic. It has excellent recuperation characteristics, as anyone who has uncorked and recorked a bottle will recognize. Rubber, on the other hand, is incompressible; it is hydraulic in its response to applied pressure. By combining the two materials, a resultant product is obtained which has many of the best qualities of both components.

Compressibility and flow characteristics can be controlled, *Fig.* 2, and combinations produced which are nearly as compressible as cork, or almost as incompressible as straight rubber. This characteristic is determined largely by the relative quantities of

Oil Filter

A Buna S rubber gasket seals the cover of this automotive oil filter. Good oil resistance and resistance to cutting action of the narrow flange are requirements met by a compound with a Shore A hardness of 90. Rings of the material can be lathe-cut economically from tubes.



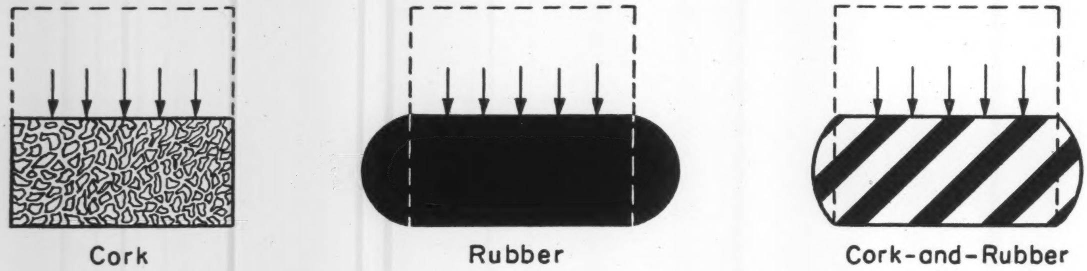


Fig. 2—Difference in compressibility among cork, rubber, and cork-and-rubber. Cork is compressible and does not flow laterally; rubber is noncompressible and flows laterally; cork-and-rubber properties can be adjusted

granulated cork to rubber, but is also affected by size of the cork granules.

Cork is almost completely unaffected by petroleum derivatives and may contribute a quality of inertness and resistance to swell. It is little affected by age, helping preserve the life and properties of a combination material. Additionally, the high frictional qualities of cork are largely retained in a combination of cork and rubber.

Cork-and-rubber materials are usually mottled, the mottling being fine or coarse, pronounced or subdued, depending on the amount and type of cork used. In most such materials, rubber is the continuous phase of the composition, the cork being present as a filler, although in many cases the proportion of cork is at least equal to that of rubber by weight. The compositions are either neutral or pigmented, or may contain carbon black and other fillers and compounding ingredients which may affect appearance.

Composition: Cork-and-rubber gasket materials are vulcanized compounds of natural or synthetic rubber and conventional rubber compounding ingredients in addition to cork. Of the synthetic rubbers, the GR-S, nitrile, and neoprene types are most generally used. Choice of polymer influences chemical properties of the resulting compound, but in all cases the physical property of controlled flow or compressibility is retained. Due to its organic nature, cork can be combined most readily with those rubbers which cure at moderate vulcanizing temperatures.

Available Forms: Cork-and-rubber is most generally furnished as sheets split from blocks. A standard size is 36 by 36 inches, and any desired thickness from 1/32 to ½-inch or more may be obtained.

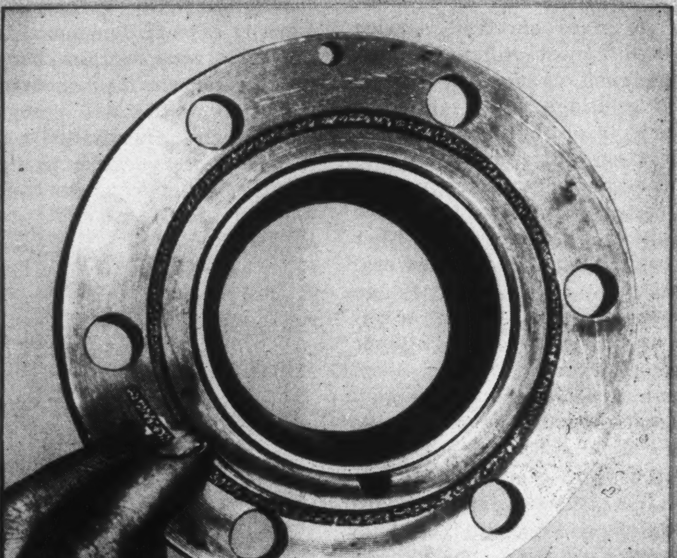
Various styles of tape and ribbon are available. One useful variety is a chemically blown cork-and-rubber material with fabric reinforcing back, to which is applied a pressure-sensitive adhesive.

To a limited extent, cork-and-rubber materials can be extruded, usually in tube form as a preliminary step to the cutting of washers or rings. Tubes can also be made by wrapping and curing the material on a mandrel.

It is entirely practical to mold many sizes and shapes in cork-and-rubber compounds. However, the characteristic properties of the combination are best preserved by die cutting or machine shaping from

Two-Speed Axle

Cork composition is used as a seal for this pinion-bearing cage in an Eaton two-speed axle because of its compressibility. A narrow groove cut in the flange face permits metal to metal contact of the cage and housing for proper spacing with correct gasket deflection. Relief for side flow of the gasket is not needed.



blocks and sheets. Cork-and-rubber lends itself to die cutting and machine finishing operations, and these are the most generally used methods of fabrication.

Cost Factors: Since considerable variation is possible in proportion of cork to rubber, and in type of rubber employed, the price range for cork-and-rubber materials in sheet form is likely to be rather wide. For example, a composition of reclaim rubber and cork will cost very much less than a specification material made with one of the higher-priced synthetic rubbers. Cork-and-rubber is generally higher priced than cork composition and vegetable-fiber sheet packings, and about the same or a little lower than the higher-grade rubber-asbestos compositions. Its cost is usually lower than that of high-quality straight-rubber sheets, based on the same polymer.

Fabrication factors may affect cost comparisons with other materials. Where the parts involved are plain rings, they may be made more cheaply from cork-and-rubber by slicing from tubes than by die cutting from cork-composition or vegetable-fiber sheets. Compared with straight rubber gaskets, cork-and-rubber gaskets may be less expensive, depending upon quantity; the material lends itself to die cutting and machine finishing at rates which may be more favorable than individual molding with straight rubber.

Properties and Limitations: Using the same yardsticks as previously outlined, cork-and-rubber rates as follows:

Imperviousness: Since the rubber binder is the continuous phase of these materials, they are essentially impervious to gases and liquids. Some porosity may be experienced in a part having a thin, delicate cross section, but assuming that no such special condition exists, imperviousness of cork-and-rubber is inherent and does not need to be induced by compression.

Achieving complete contact between gasket and flanges: Cork-and-rubber requires virtually no pressure to promote intimacy of contact between gasket and flange faces. It compresses easily and flows into irregularities effectively under light pressures.

Maintenance of complete contact of gaskets to flanges: This is a function of the elastic and frictional properties of most cork-and-rubber compounds. A cork-and-rubber gasket stays put in a joint, even when oil or other lubricant is present, because the material does not flow or extrude appreciably, and the cork granules which are exposed at the surface resist sliding on the flange. Elasticity of the material is quite good at normal temperatures, although some compression set will occur at elevated temperatures and under prolonged pressures. Cork-and-rubber will usually become strongly adherent to meal flanges in the course of time, and as has been pointed out before, this is highly beneficial in keeping a tight joint.

Compatibility between gasket and its environment: Chemical properties of cork-and-rubber are largely the result of the type of rubber with which it is compounded. Cork is organic and should not be used under strongly alkaline or acidic conditions, but it withstands all petroleum products and most other solvents quite well. Cork-and-rubber materials are likely to swell a bit in contact with aqueous solutions, but this is primarily a matter of mechanical release of forces of compression in the cork granules which occur during manufacture. It is not usually an indication of deterioration.

Temperature resistance of cork-and-rubber is about the same as for other organic gasket materials; that is, it is best used at temperatures below 160 F. In some cases, it may perform satisfactorily in the range of 250 F and materials compounded with some of the new synthetic rubbers based on polyacrylic esters may be used at temperatures in excess of 300 F.

Typical Uses: Where the high distensibility of straight rubber is not required, or where alkaline conditions are not encountered, cork-and-rubber can do many of the jobs usually associated with rubber, often at lower cost, and it will do practically any of cork compositions' characteristics jobs better, but probably at a little higher cost. The wide range of usefulness of cork and rubber is indicated by several representative examples:

Metal-to-metal joints: In order to preserve close tolerances and alignment of internal parts, and also to avoid overstressing the gasket, it is often desirable to bring joints together metal-to-metal. This can be done by providing a groove for the gasket in one member. Cork-and-rubber is excellent for this kind of flange design and requires no allowance for side flow.

Joining light or fragile members: Automotive tail lamps exemplify a service involving compensation for rather wide tolerances and irregularities, and cushioning action more than outright sealing. This application generally involves the gasketing of a joint between a glass or plastic lens and a metal stamping forming the reflector or the housing for the complete unit. The cork-and-rubber material generally used here is chemically blown for extra softness. This application also uses conventional cellular rubber, which is still softer. However, the cork-and-rubber gasket is usually more rigid and may be easier to handle for rapid assembly.

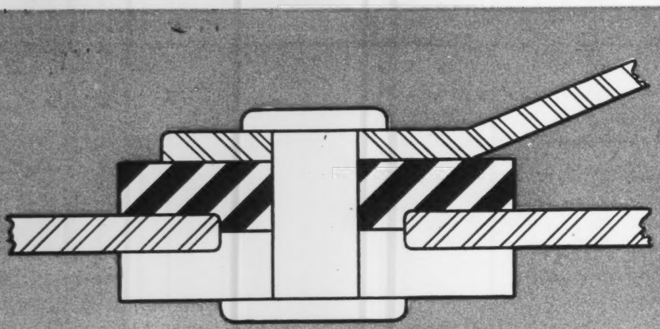
Joining heavy, irregular members. Electrical transformer cover and bushing gaskets provide an example of a heavy-duty, long-time installation. Also, tolerances are rather wide, since this construction is rugged and massive. Cork and neoprene has been a widely used material for this service. It resists the effects of climatic conditions on the outside, and effects of insulating oils on the inside. These gaskets are often deliberately cemented in place to take advantage of the permanent tightness and the come-and-go with temperature changes which is possible when the gasket adheres to the flanges.

Joints for fuel and solvent resistance: The flanges connecting airplane fuel cells and wing tanks require gaskets with high fuel and solvent resistance. A cork and nitrile rubber composition has been considered standard for this service for some years. The particular grade generally favored is that meeting the requirements of specification MIL-G-6183, Class I, firm.

Cork Composition

Structure of cork is cellular rather than fibrous, accounting for its unique properties. These very minute cells contain air, are surrounded by a membrane of cellulose, and are cemented together by a natural resin. Application of pressure merely compresses the air within the cells, and deformation is almost entirely in the direction of the applied pressure.

Besides this interesting property, the material is noncapillary, light in weight, does not deteriorate with age, is economically inert, and has a high



Condenser Terminals

Dielectric strength plus good oil resistance are needed for terminal seals on oil-filled condensers. A brown neoprene stock with 65 Shore A hardness is used.

coefficient of friction. In its natural, unprocessed state cork is highly variable in texture, quality and size. Hence, it is best used in combination with other materials, as in the cork-and-rubber compounds previously described, or in the form of compositions.

Cork compositions are made by combining graulated cork with a suitable binder under heat and pressure. The principal variables, which are manipulated to produce different types and grades, are:

Granule Size: This is a factor of little importance in determining physical property differences. Screen limits vary with different manufacturers with the objective of obtaining maximum yields of desired particle sizes from the grinding operation.

Binder: In a typical gasket composition, proportion of cork to binder is approximately 70/30 by weight. Binders are generally plasticized protein (glue-glycerine) or resin. Rubber cements and latexes are sometimes used, but the protein and resin types are by far the more popular. Protein binder materials are generally favored, since they are more permanently flexible and stable in compression properties and dimensions. Resin binders are more resistant to fungus and weather exposure. They also resist acids better.

Density: Weight per cubic foot is determined by the amount of loose mixture of cork and binder that is compressed within a given mold size. After the material is set to the size to which it has been compressed, it has acquired the characteristic density which was planned for it, along with certain other characteristics which follow density quite closely. These other characteristics are principally tensile strength and compressibility, the former varying directly with density and the latter inversely. Densities of gasket compositions range from approximately 14 to 30 pounds per cubic foot. Materials running as low as 10 or 12 pounds per cubic foot and as high as 40 pounds per cubic foot have been made for special applications.

Cork composition is light tan or buff in color. That the material is essentially a mass of granules cemented together by a binder is generally evident from the appearance of the sheet. However, grades made with extremely fine granulated cork may look quite homogeneous.

Cork composition is sometimes miscalled corkboard. The latter is a reddish-brown, lightweight, boardy material used for low-temperature insulation. It is friable in thin sections and is quite unsuited for gaskets. Natural resins, activated by the high baking temperature, are the sole binding agent in corkboard. Cork composition, on the other hand, is always compounded with added binder.

Forms Available: Since cork does not flow under pressure and requires the application of considerable heat to accomplish relaxation of the cells and to set the binder, it is economical to mold cork only into the simplest of shapes. Industry practice is to form it into mats or blocks several inches thick, from which sheets of any desired thickness may be split by means of a band knife. Sheet sizes vary among several manufacturers, but are quite generally in the range of 6 to 12 square feet.

Cork composition gaskets are generally produced by die cutting, usually with simple wood-backed steel-rule dies. Shapes which are not susceptible to die cutting may be produced by some combination of machine finishing operations, including sawing, slicing, sanding, grinding, boring and drilling. Some manufacturers have developed techniques for the production of wheels, ribbon, tubes, rods, logs, and even continuous sheet or roll goods, but these forms are usually for specific purposes other than gaskets.

Cost Factors: Cork composition is the cheapest of the efficient, soft gasketing materials. Plain paper and rag felt may cost less, but are not suitable for many of the same applications. Density is the most important variable affecting the cost of the prime material.

Fabrication losses may affect the cost relationship between cork and other materials. For example, rubber or cork-and-rubber produced as a tube and sliced into rings may lead to a lower cost for the finished ring than fabrication from solid sheets of cork. For another example, it is rarely practical to use cork in a thickness less than 1/16-inch, whereas fiber gaskets may often serve the same application in a thickness of 1/32-inch. This may occasionally alter the normal cost relationship in favor of the fiber.

Properties and Limitations: Cork composition rates as follows:

Imperviousness: When engaged in sealing fluids, cork composition is sufficiently impervious to hold moderate pressures. However, when dry it may be slightly permeable to air or gases, due to the presence of minute voids between granules which have not been entirely closed by the forming or flange pressures.

Effecting complete contact with flange surfaces: Cork rates well in this respect, being a soft, conformable material which exhibits little if any side flow when compressed.

Maintenance of contact: Cork is a very resilient material and keeps pushing back against the applied pressure over a long period of time. This action is favored by the swelling action of most fluids on the sealing edge of the cork gasket. This tendency to swell when wet is really a release of the forces of compression created at the time the granules were originally compacted in forming the composition. Sustained high temperatures in excess of 160 F tend to produce a condition of permanent set, but the material as a rule remains resilient and able to continue functioning as a gasket.

Compatibility with environment: Cork composition is unaffected by oils and aromatic solvents. It does not take sustained contact with water too well and is rather readily disintegrated by alkaline solutions. Plasticizers are likely to be extractable in water, and cycles of alternate wetting and drying produce pronounced shrinkage and hardening.

Temperature response of cork composition is just about the same as that of any organic material. It should not be used at temperatures in excess of 160 F. It becomes hard and unyielding at subzero temperatures, but is not permanently affected by exposure.

Because of contained moisture and inherent acidity, cork compositions may encourage corrosion in aluminum and magnesium alloys, and to some extent in stainless steel. Fungus resistance of cork composition is very poor if the material is made with protein binder; fairly good if the binder is a phenolic resin. Protection is possible by suitable external treatments of finished parts. Fungicides incorporated into the binders do not penetrate the cork granules and, therefore, do not protect cut surfaces.

Typical Uses: Because of its combination of softness and resistance to liquid penetration, and its compressibility, cork composition is suited for many mass-production applications involving the mating of rather irregular surfaces where temperatures are moderate and internal pressures are low. The automotive and affiliated industries consume more cork gaskets than any other. Cork gaskets are valuable in applications involving widely spaced bolts and light construction, in which bowing is inevitable. Another type of application where cork is often used is the joining of glass or ceramic parts to metal. Tolerances are very wide in such assemblies, and cork can be helpful in providing a shock-absorbent cushion for the glass and ceramic components.

Rubber and Plastics

Because of the many existing reference works on natural and synthetic rubbers and plastics, no attempt is made here to discuss them except from the standpoint of their specific adaptation to gasketing.

Rubber Used for Gasketing: General properties and special characteristics of natural rubber and of the synthetic rubberlike materials important in gasket work are shown in *Table* 2. Each rubber, however, has certain characteristics worthy of further comment.

CRUDE OR NATURAL RUBBER: Petroleum oils and fuels are natural enemies of crude-rubber compounds, causing them to swell and soften. Excessive swell is also produced by turpentine, carbon bisulfide, chloroform, and carbon tetrachloride. Vegetable oils, on the other hand, cause only moderate swelling, while glycerine, ethylene glycol and plain water cause negligible volume increase. Vulcanized compounds can be made to resist moderate concentrations of most inorganic acids, alkalis, and inorganic salts. Natural-rubber compounds will withstand continuous heat up to 160 F, although surges of intermittent exposure to 250 F may be tolerated quite well. Low-temperature flexibility is good at minus 65 F.

BUTYL RUBBER: This copolymer of isobutylene and isoprene shows excellent resistance to vegetable oils and to dilute organic acids and alkalis. Its high resistance to gas permeation accounts for many of its applications, such as gas masks and automobile tire inner tubes. Operating temperatures range from about minus 65 to 250 F. However, the vulcanizates of butyl rubber are inferior with respect to compression set and lacking in solvent resistance. It is not an important raw material to the gasket industry.

STYRENE TYPE: This general-purpose rubber is known in Europe, and to some extent in this country, as Buna S, and is also known here as GR-S. It is a copolymer of butadiene and styrene, and in general employs the same compounding ingredients

Table 2—Properties of Commercial Synthetic Rubbers*

Property	Natural Rubber	Butadiene (Buna-S; Styrene GR-S)	Butadiene (Buna-N) Acrylonitrile		Neoprene		Butyl	Thiokol		Silicone Rubber	Poly-acrylates
			Low Swell	Hi Swell	Type GN	Type W		Type PR-1	Type ST		
Specific Gravity (pure gum)	0.92	0.94	0.98	0.98	1.23	1.23	0.92	1.34	1.34	0.98	1.1
Tensile Strength (psi, max)											
Pure gum	3000	400	600	600	3500	3500	3000	300	300	200–450	...
Black reinforced	4500	3000	3500	3500	3500	3500	3000	1500	1500	...	2500
Elongation (%, max)	700	500	600	600	600	600	700	400	400	300	500
Tear Resistance	3	4–5	4	4	3	3	3	4–5	4–5	4	4
Aging Resistance:											
Ozone	4	5	5	5	1	1	1	1	1	1	2
Oxidation	3–5	3–5	3–5	3–5	1–3	1–3	1–3	1–3	1–3	1	2
Heat	3–4	3–4	3	3	2	2	3	5	5	1	1
Static (shelf life)	3	3	3	3	2	2	1	3	3	1	2
Compression Set Resistance	3	3	2	2	4	3	3–4	5	5	1	3–5
Oil Resistance:											
Low aniline	5	5	1	3	4	4	5	1	1	5	1
High aniline	5	5	3	1	3	3	5	1	1	3	1
Gasoline Resistance:											
Aromatic	5	5	5	3	5	5	5	1	1	5	1
Nonaromatic	5	5	4	1	3	3	5	1	1	5	1
Acid Resistance:											
Dilute (under 10%)	3	3	3	3	3	3	1	4	4	4	4
Concentrated (except nitric and sulfuric)	3–4	3–4	3	3	4	4	1	4	4	4	4
Alkali Resistance:											
Dilute (Under 10%)	3	3	3	3	3	3	3	5	5	4	5
Concentrated	4	4	4	4	3	3	3	5	5	5	5
Low Temperature Resistance	3	3	4	4	4	4	3	4	4	1	5
Impermeability to Gases	4	4	4	4	3	3	1	3	3	3	3
Water Resistance	3	2	2	2	4	4	3	4	4	4	5

* Code for main part of table: 1—excellent; 2—very good; 3—good; 4—fair; 5—poor.

and fabrication methods, and vulcanizes in about the same manner, as natural rubber.

ACRYLONITRILE TYPE: Often shortened to "nitrile rubber," this type is also known as Buna N in Europe and by a variety of trade names in this country. It is a copolymer of butadiene and acrylonitrile. The vulcanizates have good physical and heat-resistant properties and are characterized by extraordinary resistance to the swelling action of petroleum oils, fuels and solvents. Nitrile-rubber compounds also have the interesting property of being resistant to the natural forces of adhesion which often cause rubber to adhere to adjacent metal parts.

CHLOROPRENE TYPE: More generally known as neoprene, this rubber is a polymer of chlorobutadiene. It can be compounded, fabricated, and vulcanized like natural rubber, but requires no sulphur to effect vulcanization. It is easier to handle than the acrylonitrile types, and the products are stronger and more resistant to ozone and corona, although not quite so good in respect to oil, fuel or heat resistance.

POLYSULFIDES: Marketed under the name "Thiokol," these rubbers can be compounded, fabricated, and vulcanized, although with more or less difficulty. They are more thermoplastic and less heat resistant than other synthetics, and are characterized by strong odors. However, they have the best overall solvent resistance of the commercially available rubbers, although no superiority over natural and GR-S is evident in polar fluids.

SILICONES: The silicones are in a class by themselves among rubber materials when it comes to heat stability and low-temperature flexibility. They also possess excellent dielectric properties and good oxidation and outdoor weathering resistance. Silicone rubber has good resistance to high aniline-point oils, but reacts unfavorably with oils of low aniline point and with aromatic and nonaromatic gasolines. It deteriorates if used in contact with steam under pressure. Silicone rubber is somewhat lower than others in tensile strength, tear resistance, ultimate elongation and abrasion resistance. Therefore, usefulness of silicone rubber is generally considered as being limited to static sealing applications, and where its wide operating temperature range (from about −100 to +400 F) is needed. A special virtue of silicone rubber is that it does not stick to metal surfaces at high temperatures and, while in many of its physical and chemical properties it is quite similar to the fluoroethylene thermosetting resins, it is actually more like a true rubber in its compression and extensibility characteristics, and in its ability to be molded and vulcanized to special shapes.

Specifications: Two specifications, MIL-R-3065 and MIL-C-3133 covering solid and cellular rubber compounds respectively, have been found useful in that they permit the complete description of a desired rubber compound by the identifying symbol developed from a table of physical property requirements along with suffixes denoting special requirements. When properly used, they are valuable instruments, but if the user is not conversant with the properties and limitations of rubber compounds, his experience with these specifications may be unfavorable, for several reasons.

First, a virtually limitless number of compounds could be called for by specifying various combinations of properties, whereas the rubber compounders must limit their operations to a manageable assortment. Hence, a chosen compound may not be available commercially or may be available only from a specialist.

Also, it is quite possible to combine properties and special requirements into a designation covering a material which cannot be made.

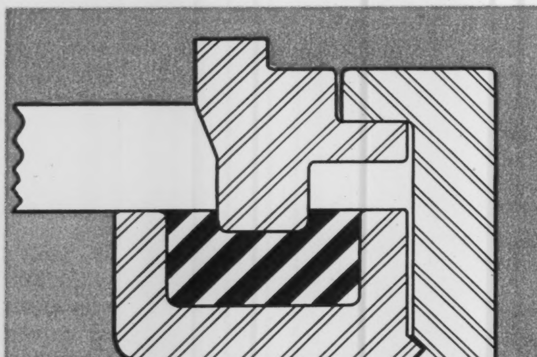
The natural tendency is to overspecify; that is, to ask for an unnecessarily high level of properties. This contributes to difficulty of procurement and uneconomic cost of the gasket.

General Design Properties: The term "rubber" covers several basic elastomers, each of which is capable of being compounded to give materials of limitless variety. Fortunately for the designer, most of these variations are concerned with chemical, solvent, and temperature response; and the factors that the designer must know about for drawings and calculations are common to all forms of rubber and to rubber-like plastics. These can be described briefly and somewhat generally in several broad terms.

Rubber is incompressible. It can be deformed with more or less ease depending upon hardness and cross section, but a true rubber compound cannot be reduced in volume. Therefore, room for flow or deformation must be provided. Or, conversely, it may be necessary to completely or partially confine the rubber to control amount of deformation or flow which occurs when pressure is applied.

Rubber is extensible. As in the case of incompressibility, this property of extensibility can be a two-edged proposition, offering design possibilities on the one hand and possibly requiring design and assembly controls on the other hand. Rubber's extensible properties are very valuable when it is necessary to assemble a gasket over a projection or shoulder, perhaps with the idea of having it snap tight within a groove. Except for some plastics, rubbers are the only materials that will stand this kind of treatment. On the other hand, the very stretchiness of rubber encourages abuse in the form of overstretching, and the gasket may not always return as planned to its original size.

Impermeability: In the sense of its ability to serve as a tight barrier against the passage of gases or fluids, rubber is highly impermeable. Neoprene and butyl rubber are outstanding in this respect, but all types of rubber are adequately impermeable for all practical gasketing purposes, and no supplementary measures such as compression or coatings are re-



Quick-Disconnect Coupling

Excellent abrasion resistance is needed in this coupler, and a relatively hard Buna N rubber compound (92 Shore A) is used. Gasoline, oil and aromatic-solvent resistance is also high.

quired to induce this quality of imperviousness.

Effecting complete contact of gasket to flange: Very little flange pressure is required to accomplish intimate contact with the face of a rubber gasket. The material conforms, flows, and equalizes easily in accommodating itself to the irregularities of normal flanges. Differences exist, according to the hardness of rubber being employed. The most commonly used hardnesses are those below 80 Shore A, and within this range the foregoing statement holds true. For compounds over 80 in Shore Durometer hardness, contact pressure is likely to approach that required of rubber-asbestos composition sheets. Conversely, a soft rubber compound will conform more easily than a medium to hard compound, but may present other difficulties such as excessive extrusion.

Maintenance of complete contact of gasket to flanges: Rubber has sufficient elasticity to follow well the movements of the flange surfaces. The best compounds for gasket use are those which have been formulated for low compression set, specified with suffix B in the MIL-R-3065 identification system. If the gasket is not confined, it may tend to walk out of the joint with successive tightenings of the bolts; or may fail through rupture if overstressed.

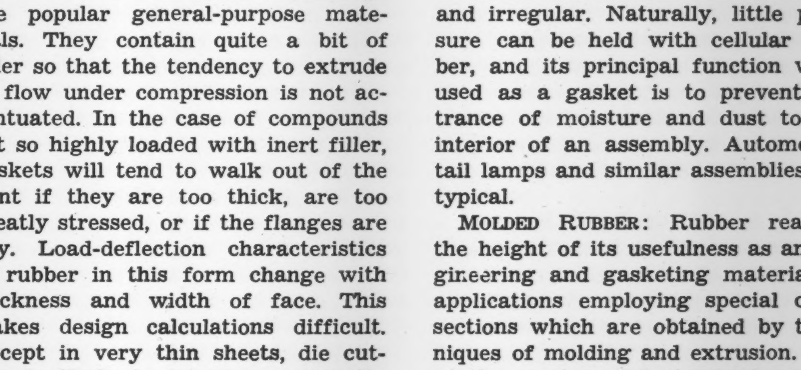
Compatibility between gasket and its environment: As is noted in the references to the various types of synthetic rubbers, they vary considerably in their reaction to contact with petroleum derivatives, acids, alkalis, solvents, ozone, etc. These inherent compatibilities are so affected by compounding, however, that it is impractical to do more than indicate the possibility of a high degree of variation. Heat resistance of rubber is about the same as that of other organic materials, and rubber compounds other than silicones are best used at ambient temperatures not over 160 F. Low-temperature flexibility is highly variable according to the elastomer being employed, but compounding, and especially choice of plasticizer, has a profound effect upon this basic characteristic. Since it does not absorb and hold moisture, a rubber compound is not likely to cause corrosion of flanges but, depending upon the metals employed, some staining or other reaction may occur due to certain of the compounding ingredients. For example, silver tarnishes readily in contact with rubber which has been compounded with sulphur.

Forms and Uses of Rubber: Rubber is best used in situations where controlled deformation is a feature of the design. The ordinary type of flanged joint wherein the gasket is subject to straight compressive stresses does not utilize rubber's unique properties to any appreciable extent; and in fact this type of joint tends to accentuate those properties of rubber which are least desirable from the standpoint of gasketing. At this point, it is well to take a look at the various forms in which rubber is customarily processed or fabricated, and possibly suggest types of applications for which each is suited.

SHEET RUBBER—SOLID: Many pipe-flange gaskets in systems handling aqueous solutions at moderate pressures and temperatures are made from rubber. If no petroleum oils or derivatives thereof are present, GR-S and natural-rubber compounds made in the form of what is commonly known as "red rubber sheet packing" are popular general-purpose materials. They contain quite a bit of filler so that the tendency to extrude or flow under compression is not accentuated. In the case of compounds not so highly loaded with inert filler, gaskets will tend to walk out of the joint if they are too thick, are too greatly stressed, or if the flanges are oily. Load-deflection characteristics of rubber in this form change with thickness and width of face. This makes design calculations difficult. Except in very thin sheets, die cutting is likely to introduce concavity and tapering of edges, which may be objectionable. When die cutting from thin sheets, the material is likely to be too easily deformed for accurate die cutting. This is countered in some instances by the use of fabric insert compounds.

SHEET RUBBER—CELLULAR: Of the two types of cellular rubber—closed cell and interconnected cell—the former has several advantages for gasket work. Most evident of these is its ability to resist passage of moisture. Both types are an approach to the problem of making a truly compressible rubber material, which will respond to applied pressure in a "pneumatic" fashion. In fact, applications for cellular rubber are very similar to those in which cork composition is also used. It is especially well adapted to gasketing between members which are rather fragile and irregular. Naturally, little pressure can be held with cellular rubber, and its principal function when used as a gasket is to prevent entrance of moisture and dust to the interior of an assembly. Automotive tail lamps and similar assemblies are typical.

MOLDED RUBBER: Rubber reaches the height of its usefulness as an engineering and gasketing material in applications employing special cross sections which are obtained by techniques of molding and extrusion. One of the most useful standard molded forms is the well-known O-ring, which will be discussed later. Numerous other self-energizing types of gaskets can be devised with full assurance that their production will be



Transfer Case Cover

Organic fiber sheet packing saturated with a glue-glycerine impregnant is used for this transfer-case cover gasket. The tough gasket has high strength, and seals effectively against gasoline, oil and water under wide temperature and humidity variations.

quite possible and practical by molding from rubber. Manufacturers of hydraulic and pneumatic devices are particularly dependent upon molded rubber for many sealing applications, including both packings and gaskets.

One of the limitations to the use of molded rubber parts is cost. Rubber molds are costly compared with the relatively simple tooling required for producing die-cut or lathe-cut parts. Therefore, molding of rubber is most feasible when quantities are sufficient to justify mold costs, and when by molding the loss of centers or other scrap can be minimized.

LATHE-CUT RINGS: One of the most frequently used techniques for making rubber rings and washers of rectangular cross section is to slice them from tubes. The tubes can be made either by extrusion or by a process of laminating. The latter involves wrapping a mandrel with a sufficient number of plies of uncured stock to build up the required diameter or wall thickness. Some means of applying pressure, as by wrapping with cloth tape, is employed during the vulcanizing cycle, after which the tube is ground (if necessary for finish or accuracy) and sliced manually or on automatic equipment.

Saving in mixed stock which results from this form of fabrication frequently enables rubber to compete with materials which are ordinarily considered less costly. Manufacturers of electrical equipment such as transformers and lightning arrestors have found it quite feasible to purchase square or rectangular cross-section rings produced by slicing from tubes, and in their assembly operations to distort these simple rings to various other shapes such as triangles and rhomboids. This system is more flexible and less costly than purchasing parts molded to the final shape.

MACHINE-FINISHED PARTS: Rubber can sometimes be machine finished by processes of slicing, grinding, punching, sanding, etc., but this type of production is not often practiced except for the production of small quantities; or where it has been found feasible to purchase a standard, mass-produced part and by a small alteration such as the grinding of a bevel, make it into a desired part.

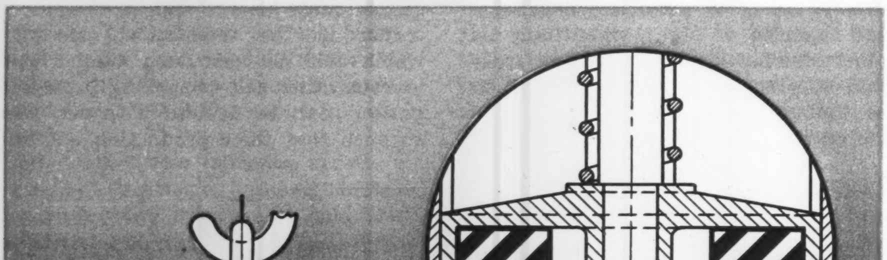
O-Rings: In essence, the O-ring is a molded rubber packing. But from the standpoint of the engineering attention it has received, the precision with which it is manufactured, and the care with which its quality is controlled, it transcends the usual techniques of commercial rubber molding. A considerable variety of compounds is available varying in hardness, fluid resistance characteristics, and high and low temperature response. General information on installation and gland design is contained in specification MIL-P-5514A.

Some of the reasons for the high regard in which the O-ring is held by designers are:

1. *Simplicity:* Not only is the O-ring itself a simple item as to shape—its use also calls for the simplest of groove or channel designs. This simplification contributes to low fabrication costs, compact mechanism and foolproof performance.
2. *Ease of installation:* In general, all that is required is to snap the O-ring into place and complete the assembly.
3. *Standardization:* Physical property specifications, sizes of the rings themselves, and the sizes of the grooves, cavities, or counterbores in which they fit, have all been standardized. Basic dimensional information is included later.
4. *Versatility:* O-rings can be used for dynamic or static seals.
5. *Effectiveness:* O-rings are used routinely for holding pressures up to 1500 psi. When supported by a back-up member such as a ring of leather or plastic, O-rings have proved able to hold pressures in the range of 3000 psi. The purpose of the back-up ring is to prevent excessive extrusion of the O-ring into the clearance space between the members.

If only its virtues are examined, the thought is created, "why does anyone use anything else?" Some of the factors impeding wider acceptance of the O-ring are:

1. *Extrusion:* When holding high pressure or vacuum, an O-ring may extrude into clearance spaces, and accidental damage to one of the adjacent members may prove fatal to the seal.
2. *Vulnerability to environment:* Instead of a thin edge being exposed to the sealed fluid, an O-ring is almost totally exposed. Its effectiveness depends entirely upon its retention of resilience. Anything which destroys the resilience of the O-ring produces failure of the joint. There is usually no follow-up device and no opportunity to renew the seal by tightening of bolts.
3. *Abrasion:* Even when used as a static seal, pressure pulsations cause a rubbing of the O-ring against confining metal parts and may lead to wear and failure.
4. *Cost:* The adjoining surfaces should usually be superfinished or chromium plated, and this requirement may make the joint uneconomical.



Tank-Truck Emergency Valve

A compressible gasket, highly resistant to gasoline and fuel oils, is needed for this emergency valve. To prevent wedging, the gasket must not flow under the heavy spring load. Requirements are met by a cork and Buna N rubber material with a high cork content.

Fluoroethylene Polymers: Sold under the trade names Teflon (polytetrafluoroethylene), Kel-F (polytrifluorochloroethylene) and Fluorothene (polychlorotrifluoroethylene), fluoroethylene polymers are distinguished by a number of unusual properties. These include: chemical inertness; toughness over a wide temperature range; resistance to high temperature; extremely low dielectric loss over a wide range of frequencies; resistance to all solvents, including high boiling ketones, boiling sodium hydroxide, aqua regia, hydrofluoric acids, and fuming nitric acid; low friction; and nonadhesion.

Teflon has superior physical properties and is usable over a wider temperature range than Kel-F, but the latter is likely to be less costly and more versatile in fabrication. Teflon's remarkable range of working temperatures extends from below minus 90 F to approximately 480 F.

Kel-F is less resistant to softening at temperatures over 300 F, and is adversely affected by ultraviolet light and X-ray exposure.

These plastics are supplied in standard shapes: sheets, rods, tubes, and tape; as molding powder—shredded and granular; and in the form of suspensoids—stable aqueous dispersions containing 50 per cent solids. Complex articles are formed by machining the standard shapes. Teflon cannot as yet be molded by the conventional techniques used with other plastics because it does not melt and flow. It can be molded into simple shapes, however, by an adaptation of the compression molding process. As a suspensoid, it can be applied in successive thin (about 0.001-inch) coats, each followed by fusion at 500 F. Thus, only high temperature resistant base materials may be treated in this manner.

Teflon gaskets in a wide range of sizes are offered by several suppliers in solid, jacketed, and spiral-wound styles. The design considerations involved in each case are:

SOLID TEFLON GASKETS are produced by die cutting from a molded sheet, by slicing from the end of a molded cylinder, or by molding directly from powder. They are installed in flanges of standard design. Raised face flanges are normally used for low pressure, that is 150 to 300 psi. For higher pressures, some confining arrangements such as tongue and groove, or male and female, is used. Solid gaskets of Teflon have given satisfactory service in tongue and groove flanges at pressures as high as 30,000 psi.

Teflon is incompressible, like rubber, flowing under pressure; but gasket design for it generally follows compressed rubber-asbestos practice. There is a similar lack of resiliency in both materials. This presents a problem in operations or situations where variation in temperature changes the pressure on the gasket through expansion and contraction of the flanges and bolts. Sometimes spring-loaded bolts offer a solution in these cases.

Coefficient of thermal expansion of Teflon is about twice that of aluminum, and this must be taken into account in any design situation where the part is likely to be confined. Teflon has been reported to be subject to cold flow to a considerable extent. However, careful investigations demonstrate that the tendency is not excessive and is encountered only during the first few hours after the load is applied. Under any given temperature and pressure, equilibrium is rapidly reached, and no further change will occur unless the load or temperature is changed.

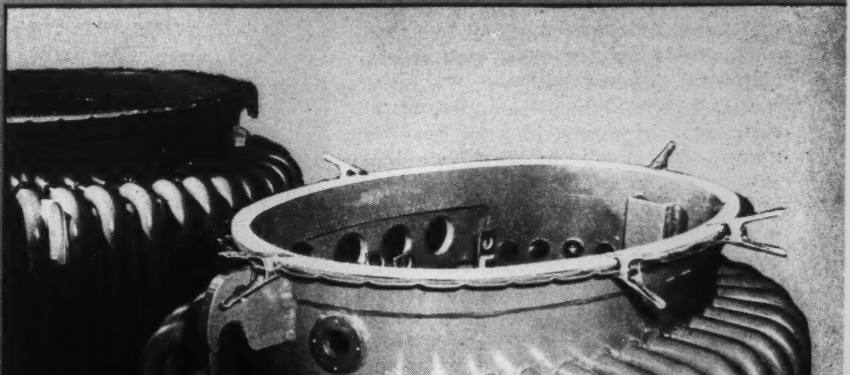
ENVELOPE GASKETS: These Teflon types were developed for glass, porcelain, and glass-lined equipment where misalignment of flanges and low bolting pressures result in failure to seat solid Teflon. Envelope gaskets are also used for those diameters larger than 24 inches, or beyond the size in which solid gaskets are available. The usual construction is the so-called "French" type, consisting of a rather soft filler covered by a jacket or envelope of Teflon. Depending on the service, the filler material may be fabric-reinforced rubber, asbestos-rubber, plain asbestos paper, and metallic and other types of materials.

SPIRAL-WOUND GASKETS: Spiral-wound metal gaskets with a filler of Teflon are made in a range of shapes and dimensions. The chemical resistance of Teflon combined with the strength of the metal provides a gasket especially suited for high pressure chemical service. Stainless steel, Monel and other metals are used, depending upon the chemicals to which the gasket is to be exposed. Spiral-wound gaskets have a mechanical "kick back" action built in, due to the shaping of the metal. They require rather heavy bolting pressure to accomplish initial seating, and they are expensive compared with ordinary flat gaskets. However, they are probably unequaled for high-pressure and high-temperature chemical service. Design calculations covering required bolt loadings generally follow the ASME *Unfired Pressure Vessel Code,* using *m* and *y* values specified for spiral-wound metal and asbestos gaskets.

IMPREGNATED-FIBER GASKETS: Many of the valuable attributes of Teflon are obtained at relatively low cost by impregnating suitable fiber sheet materials with Teflon suspensoid. The fiber most generally used in this manner is asbestos, either in the form of paper or woven fabric. The coating of Teflon protects the asbestos from chemical attack and, while little specific information is available, test

Power Transformer

Gaskets are assembled in sections on Allis-Chalmers power transformers. A projecting lip positions the gasket inside diameter, and crimps in the flange outside diameter control gasket compression.



results are said to have been very promising. The combination of blue asbestos and Teflon, in particular, should result in a highly acid-resistant gasket at moderate cost. Other types of fiber are also being considered in this connection, including glass and other ceramic types.

Paper

Types of papers of concern in this section are made from organic fibers, especially vegetable fibers. Asbestos (mineral) fiber materials have been previously described.

Untreated papers useful for gasket work run the entire gamut of paper production, including such diverse types as plain brown wrapping paper, fish paper, drawing paper, chipboard, tagboard, rag felt, etc.

Treated paper gasket materials may be made by a solution saturation process or by beater saturation. Solution saturation is the older form and still the more widely used. It consists of passing the paper stock through a tank or trough containing a liquid solution or dispersion of suitable solids such as gelatine, resin, or latex. The base paper is made from rope or kraft pulp and is purposely made porous so that it will saturate easily. By the incorporation of granulated cork in the beater, porosity and compressibility are further increased. Some use has also been made of leather fibers and cotton linters.

Beater-addition or beater-saturation processes seek to combine the fibers and the particles of saturant uniformly and in a controlled manner prior to formation of the fibers as a sheet. This type of saturated paper formation is apparently increasing in usefulness and popularity at the expense of the solution-saturated type.

Treated paper materials are also classified according to the saturant used, usually glue-glycerine, resins, drying oils, or synthetic rubber latices. The glue-glycerine saturated type is by far the most widely used of the treated papers, but it is apparently also losing ground to beater-saturated materials employing latex saturants.

Vulcanized fiber is a type of material difficult to classify, but is listed here as a treated paper occasionally used for gaskets. Because of its hardness it is generally limited to those applications in which the gasket must be highly incompressible or must serve as a shim. Vulcanized-fiber gaskets are frequently coated with a thin film of synthetic rubber to help effect complete contact between gasket and flanges.

Available Forms: All types of treated and untreated papers are supplied in sheets and rolls; usually single ply up to 1/16-inch thickness and in multiple plies or laminations for greater thicknesses. Die cutting is the usual method of fabrication of gaskets.

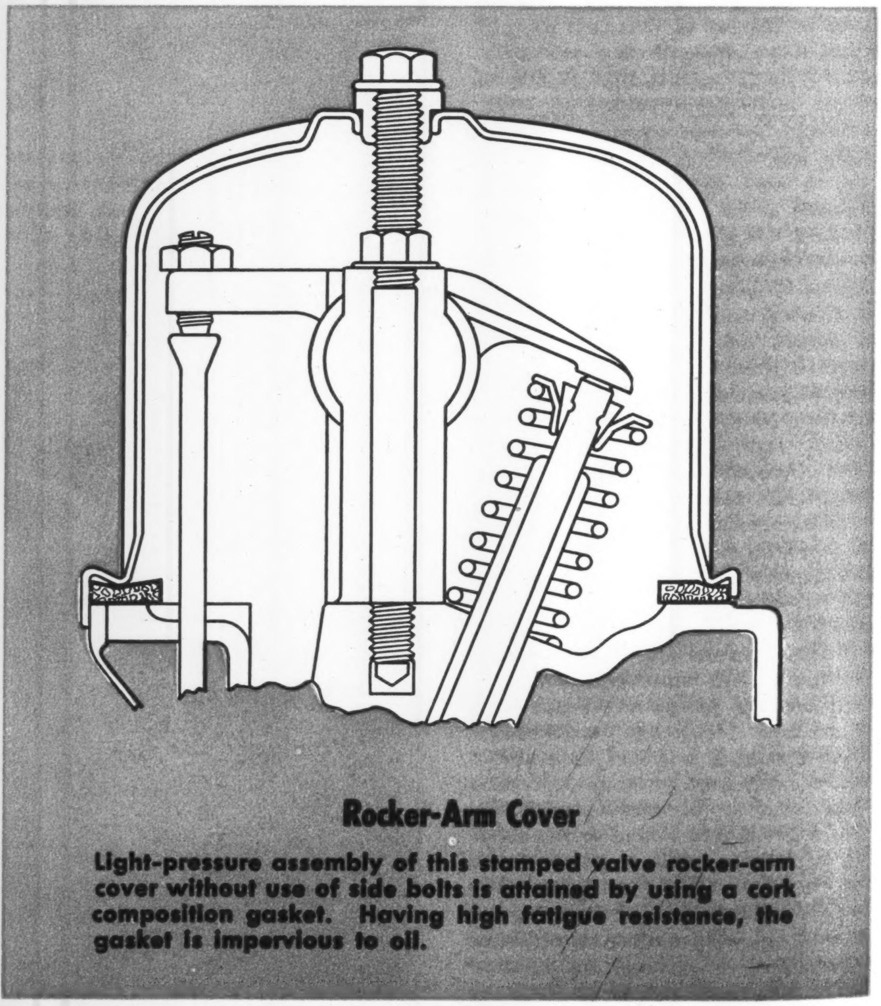
Relative Cost: Untreated paper gaskets are generally quite inexpensive—probably the cheapest gaskets obtainable. Treated papers are intermediate in cost, generally running higher than cork composition but below compressed asbestos.

Properties and Limitations: By previous standards, paper gaskets have some inherent advantages and limitations.

Impermeability: Untreated papers by their very nature are rather highly permeable, and are likely to remain so even under compression and after having been saturated with the contained fluids. Hence, they are not generally used as a fluid barrier but rather to prevent entrance of dust or merely to hold against splash of internal or external liquids. Hard or soft papers are used according to the nature of the joined surfaces. Treated papers, on the other hand, are moderately impermeable, a property which increases as the gasket is placed under compression. Solution-saturated materials are more impermeable in the unconfined state than are beater-saturated materials. The latter require compression to close the voids which are inherent in any fibrous structure.

Achieving completeness of contact: This is a factor that matters little in the case of the untreated paper. But for treated papers, a moderate amount of pressure is required to obtain an initial seating of flange to gasket sufficient to hold moderate or atmospheric pressures. This is likely to be on the order of 500 to 1000 psi on the area of the gasket, depending upon the characteristics of the gasket and the flanges.

Maintaining complete contact:



Rocker-Arm Cover

Light-pressure assembly of this stamped valve rocker-arm cover without use of side bolts is attained by using a cork composition gasket. Having high fatigue resistance, the gasket is impervious to oil.

Treated papers will hold against surprisingly high pressures. When this is a requirement, however, it is well to employ a thin gasket with long stretchy bolts which will insure follow-up pressure after the gasket has taken its permanent set.

Compatibility of gasket and environment: This is another point of little importance in connection with untreated papers since they are used only where requirements are not severe. For treated papers, the best fields of application are for the sealing of oil, gasoline, and in some cases cold water. Water service should be avoided with those materials which contain glycerine because of the extraction that will occur, followed by shrinkage and hardening of the gasket. Rubber-latex, beater-saturated types do much better in this class of service. Glycerine saturants may also cause undue corrosion of flange surfaces, and this is also avoided by using the latex-saturated types. Fungus resistance is inherently poor in plain or protein-saturated materials, fair to good in latex or resin-treated stocks. Fungicides may be added to saturants by the sheet manufacturer, or employed as external treatments by the fabricator or user.

Typical Uses: Common paper gasket applications are:

Untreated papers are generally used where service conditions are no more severe than the setting up of a barrier against the passage of dust particles or splash. They are also used where the requirement is simply for a spacer, as in the mounting of a radio speaker. Another broad field of application is where the user of the gasket has some special treatment of his own that he wants to apply to the gasket and which he cannot obtain commercially. Thus, a pump manufacturer who wants his gaskets saturated with oil buys them cut from manila paper or drawing paper, cements them in place, then applies an oil soak.

Glue-glycerine saturated papers, while being replaced in many applications by the newer latex solution-saturated and beater-saturated materials, still have the honor of being the most widely used general-purpose, soft gasket material. Where extreme compressibility is not required, it will do many of the jobs associated with cork composition. Where extreme stability, heat resistance and toughness are not required, it will do many of the jobs associated with compressed asbestos. In addition, it is available in widths of 36 inches and more and in long rolls; it is easy to stock and dispense. However, it is best used with oils and gasolines to hold moderate pressures and at moderate temperatures not exceeding 160 F. Its use is particularly to be avoided in any application involving contact with alkalies, strong acids, steam, and alternate wetting and drying.

One should always make sure of getting a so-called "specification grade," since second or third-quality competitive grades are little better than plain untreated papers. The differences lie in the amount of solids picked up by the base paper in the saturating operation.

Latex-saturated papers, particularly the beater-saturated types, perform comparably with the glue-glycerine types in general oil and gasoline services. In addition, they have certain advantages over glue-glycerine sheets: (1) nonextractable binders permit use in water and alternate wet and dry services; (2) the latex type is less likely to encourage corrosion of flanges; and (3) the latex type is generally more resistant to fungus attack.

Leather

Of the gasketing and packing materials in general use today, leather is probably by far the oldest. Most of it is from selected steer hides, and there is the further limitation that highest quality products are made only from the portion known as the butt bend. This is the section of the hide extending along each side of the backbone on the rear quarters of the animal.

As a prerequisite to its use in industry, leather must generally be tanned. The three basic tannages in the leather industry are:

1. *Vegetable or Oak Tanning:* This type employs tannin extracted from fruit, leaves, bark, wood, and roots of many shrubs and trees. It is a general custom to call any vegetable tannage an oak tannage. Today, however, most so-called oak leather is not tanned with oak bark, but with many types and combinations of vegetable material.
2. *Mineral Tanning:* This process employs mineral compounds such as chromium salts.
3. *Combination Tannages:* Blends of vegetable and mineral tanning materials are used in these types.

For many uses, impregnation as well as tanning is required. Waxes, resins and synthetic liquid polymers are used.

Forms Available: Size of the hide limits the size of parts that can be made in leather. And since all parts of the hide are not of equal quality, a further limitation is imposed. However, wonders have been performed in the manipulation of leather by experienced processors and fabricators. Machines known as leather splitters are capable of splitting hides to thin sheets. The material can be formed and molded within limits. It can be die cut. It can be skived and joined to form long strips or belts. It can be machine finished. Many efforts have been made to convert scrap leather into compositions, boards or paper formations, but so far as is known none of these has achieved acceptance for important gasketing applications.

Properties and Limitations: As with most natural products, leather is highly complex, but may be described as being made up of interwoven fiber bundles possessing a roughly directional weave, and at the same time, a complex nondirectional interlocking. This construction produces a closely knit, tough material capable of strong resistance against stresses which tend to wear, distort, or rupture it.

Even in its fully tanned condition leather is still porous and capable of breathing, as is easily understood by anyone who has noted the difference between wearing leather boots as against nonporous rubber boots. This porosity makes leather susceptible to processes such as impregnation designed to enhance its natural usefulness. And while the practice of impregnating leather originated a long time ago, new impregnating materials and techniques have come into use to cope with increasingly high pressures, and new chemical and physical conditions.

Tensile strength is highly variable, but will generally exceed 3000 psi. Leather, in common experience, is highly resistant to abrasion. This property seems to be independent of whether the grain side or the flesh side of the leather is exposed to abrasive contact.

Ability to remain flexible at extreme low temperatures is one of leather's most useful properties for modern industrial and military equipment. In the case of impregnated leather, it is to be assumed that the low temperature properties are contingent upon both the leather itself and the properties of the impregnant.

GASKET PROPERTIES: In terms of the yardsticks which have been applied herein to various types of gaskets, leather exhibits behavior as follows:

Impermeability: Leather does not have this property inherently, although it can be made almost impermeable by suitable impregnation. Thus, it is a satisfactory barrier under compression and with suitable impregnation against many fluids and some gases.

Effecting complete contact with flanges: While the ability of leather to be deformed is contingent to a great extent upon the character of the tannage and impregnation that has been employed, it does in general rate as a comparatively easy material to force into contact with metal flanges. Flanges, however, should be flat, rigid and smoothly finished.

Maintenance of complete contact: Under heavy mechanical pressures, leather tends to extrude. Therefore, leather washers and gaskets are best used in a recess. Initial tension of the bolts is depended upon to hold the joint tight, and if the bolt should loosen under shock or vibration, the joint will leak.

Compatibility with environment: When properly impregnated, leather can withstand temperatures from −70 F to 220 F. It will also be reasonably impervious to the effects of oil, gasoline, gases or fumes. On the other hand, leathers not tanned and impregnated for the conditions will be completely degreased by exposure to gasoline and alcohol, and will dry out and become brittle. Leather is never recommended for steam pressure of any type, nor for use in acid or alkali solutions.

Typical Uses: Because of its remarkable combination of toughness, pliability, strength, resistance to abrasion, and ability to hold lubricating fluids in its fibers, leather is considered an outstanding product for dynamic packing applications. It is molded into V's, U's, cups, and other shapes, or used flat as a straight compression type of dynamic packing.

One of the most important and most modern applications for leather is for back-up washers used in conjunction with synthetic O-ring packings and gaskets. In extreme high-pressure joints, rubber O-rings will extrude into the clearance spaces between metallic members unless a barrier to such extrusion is incorporated in the assembly. Leather is often used for this purpose. The pressure level at which back-up washers become necessary is rather arbitrarily set at 1500 psi. By the use of back-up washers, O-rings are suitable up to pressures of 3000 psi and even higher. The lubricating wick effect of leather is helpful in applications involving relative motion between machine parts and seals.

Another important use for leather washers is as a back-up or follower for the synthetic rubber sealing ring in aircraft fuel and hydraulic tube fittings. One noteworthy feature of this application is that the compression of the leather gasket is accomplished by a rotating nut. Many kinds of gasket materials would be injured by this type of closing action.

Combination and Miscellaneous Gaskets

In spite of the large number of natural and synthetic products used for gaskets, problems are presented which apparently cannot be satisfactorily solved by any of them. Thus, designers and vendors have shown ingenuity in combining and modifying materials to emphasize wanted properties and subdue or compensate for unwanted properties.

Laminated Materials: Purpose of laminating is usually to combine the properties of a strong but relatively incompressible material with those of a highly compressible but perhaps weak material.

For example, vegetable fiber and cork composition have approximately the same chemical properties and the same response to atmospheric conditions. Hence they are easily combined by processes of lamination and, depending upon the ultimate use, the cork may serve as the center filler or the fiber may occupy this position.

Incongruous though it may seem, asbestos and cork have been combined in a sandwich construction, the cork composition being used as a thin filler between two layers of compressed asbestos. The objective is greater compressibility.

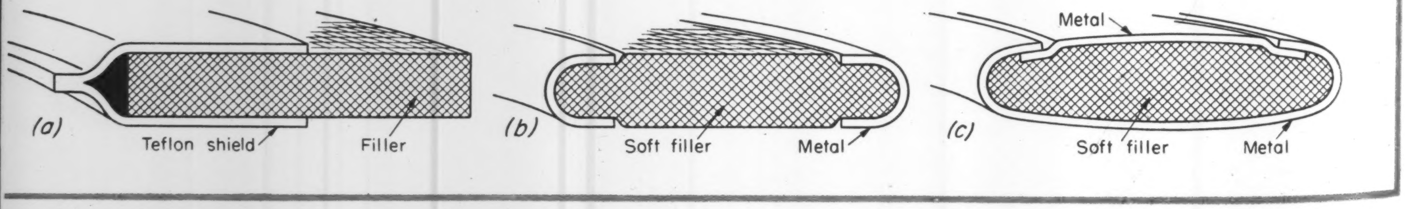
Low-cost automotive cylinder head gaskets are sometimes made by attaching a sheet of asbestos millboard to each side of a steel sheet. The steel is perforated in such a way that small prongs or stakes hold the asbestos in place mechanically.

Jacketed Types: Jacketed gaskets, *Fig.* 3, usually consist of a center filler to which has been applied a metallic or nonmetallic outer covering or envelope. The purpose of the jacket is to protect the filler material against some conditions of service to which it is vulnerable.

For example, Teflon-jacketed asbestos, rubber and other filler materials, *Fig. 3a*, are used for the gasketing of glass lined vessels and piping as used for chemical processing. Metal-clad or metal-jacketed gaskets *Figs.* 3*b* and *c*, in a wide variety of designs are used for heat or erosion resistance. Boiler gaskets and automotive cylinder head gaskets exemplify this construction.

Corrugated Metal with Soft Fillers: Such gaskets are primarily for pipe connections, are circular in shape, and are subject to moderately heavy bolting pressures. They are particularly indicated for warped flanges. A closely related construction is the serrated metal ring having serrations packed with asbestos filler, *Fig.* 4.

Fig. 3—Combination gaskets of jacketed types. Teflon-jacketed gaskets, *a,* are used for chemical service; metal-jacketed types are shown at *b* and *c*



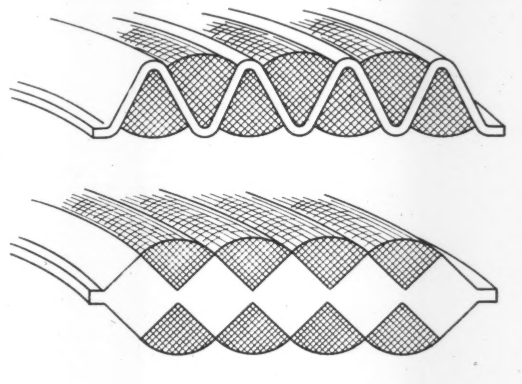


Fig. 4 — Corrugated-metal combination gaskets with asbestos filler

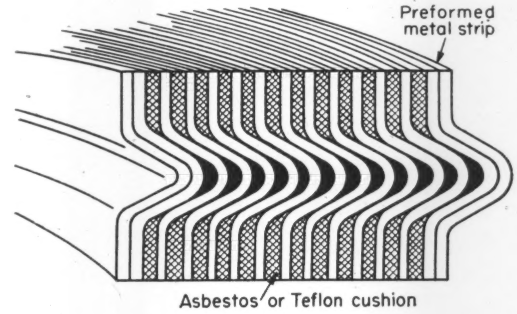


Fig. 5—Spiral-wound combination gasket

Spiral-Wound Gaskets: As illustrated in *Fig.* 5, this construction consists of plies of preformed metal and asbestos or other filler strip. A center corrugation in the metal strip gives constant tension and resilience when this type of gasket is under compression. In addition to giving a tight seal, this style is self-adjusting, noncorrosive and, in fact, has many advantages which would recommend its use where initial cost is a factor of minor importance.

Miscellaneous Gaskets: For reasons already stated, the list can go on interminably. Representative types, however, are briefly:

Flowed-in Gaskets: Applied as a liquid through a nozzle into a suitable groove or recess and then baked in place, synthetic rubber and resin compounds have found limited usage in such items as instrument-panel bezels and covers for food containers.

Gasket Pastes: This classification includes spreadable compounds which are intended to set up by air drying, or which may be designed to remain flexible indefinitely. These, of course, are relatively uncontrollable from the standpoint of installation, and very often do more harm than good in allowing the surfaces to slip.

Automotive Glass-Channel Filler: This is usually a compound of reclaim rubber and fiber, uncured, supplied in ribbon form. It is used for holding safety glass in windows and ventilating fixtures. Soap solution or oil is used as an assembly aid. A variation of this product is a cork and reclaim-rubber mix on bias-woven fabric.

Felt: Materials less permeable than felt are generally used for gaskets, but some of its mechanical uses deserve mentioning here. Ability of felt's interlocking fibers to pick up and conduct fluids accounts for its wide use as wipers, wicks, ball-bearing grease retainers, etc. Suitable impregnants improve its liquid-barrier performance, but cost is somewhat high, and applications tend to be of special nature.

Treatments and Coatings

Numerous special treatments have been devised for gaskets for purposes of resisting penetration, leveling surfaces to promote complete contact with flanges, preventing adhesion, effecting adhesion, resisting mold, protecting from heat, inhibiting shrinkage, and reducing friction. Specific treatments are:

Synthetic Rubber: Neoprene applied as a dip coat to cork composition oil pan strips for automobile engines resists oil penetration and loss of moisture, and prevents installation breakage. Thiokol applied to fiber sheet materials by doctor blade or roller helps level surfaces and promotes seating contact of these relatively unyielding materials to flange faces.

Graphite: Applied as a dry flake or mixed with oil or in a water emulsion, graphite functions as a surface leveler and adhesion inhibitor.

Adhesives: Usually of synthetic rubber or resin or combination, adhesives may be used wet or partly dry, or may be entirely dry with the idea of being reactivated by solvent or heat. They are used where an immediate permanent bond is desired, helping to keep the gasket and flange together in spite of wide temperature fluctuations and joint movement.

Fungicides: Materials such as beta-naphthol, pentachlorophenol, salicylanilide, various copper and mercury compounds are used to resist mold growth. Some are incorporated in gasket compositions, some used as surface treatment. The type of treatment and the expected degree of protection must be set up specifically between vendor and purchaser, and the latter should not be surprised if he is told that the treatment he wants cannot be employed in the vendor's factory but will have to be applied at point of usage or by a subcontractor. This is because of the hazardous nature of some of the preparations. If the reason for wanting a fungicidal treatment is to protect gaskets only during shipment and storage, formaldehyde powder dusted in cartons may be adequate if the package is vapor-tight. Some gasket materials, of course, are highly resistant to mold inherently, and extra treatments should not be specified until the need has been established.

Reflective Coatings: Aluminum paint or lacquer applied as a dip serves as reflective insulation offering some protection to gaskets located near a source of heat.

Oil or Hot Paraffin: Such materials may be applied by dipping to vegetable fiber and cork composition gaskets to prevent drying out under adverse conditions of storage.

TALC OR MICA DUST: Applied dry or in an adhesive vehicle, these materials are used to cut surface friction of gaskets and may be particularly useful in applications requiring rotation of parts to close the joint.

JOINT AND GASKET DESIGN

JOINT and gasket design must be considered together. A joint is only as good as its gasket, and the gasket may succeed or fail according to whether the joint is designed and constructed to make the best use of the properties of the gasket material. Therefore, the joint components must be thought of as a unit or as a system for effecting a seal.

In assemblies where the gland or flange design is established, gasket selection will be from materials known to work effectively in the prescribed type of design. In other instances, choice of gasket material will be dictated by some consideration which the designer is powerless to alter, and in these cases he will have to select flange designs with the properties of the prescribed gasket material in mind. It is the purpose of this section to show the mutual dependency of these two major elements.

Representative Gasketed Joints: Basic flange joints, *Fig. 6a,* are suitable for all kinds of flat gaskets, plain or jacketed; and for moderate pressures up to 200 psi. Higher fluid pressures may require some variation of this joint, such as those shown in *Figs. 6b* and *c.*

In *Fig. 6b,* the gasket wall section has been reduced to give higher gasket stress than in *6a,* without change in bolt stress. This kind of design change may also reduce cost of the gasket. The design as shown is adaptable to all flat gaskets. The tongue and groove variation of the basic flange joint, *Fig. 6c,* is useful for applying extremely high stresses to gaskets and for holding high fluid pressures. Since it completely confines the gasket, it limits the flow that might otherwise occur in many materials, especially rubber and rubber-like materials.

Metal-to-metal joints especially

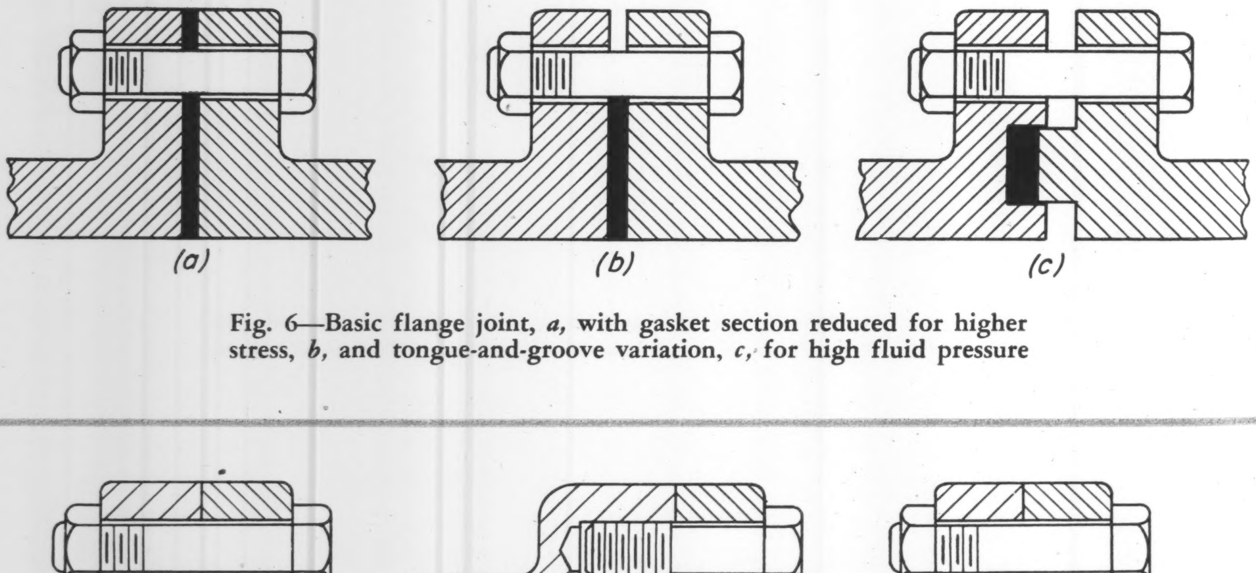


Fig. 6—Basic flange joint, *a,* with gasket section reduced for higher stress, *b,* and tongue-and-groove variation, *c,* for high fluid pressure

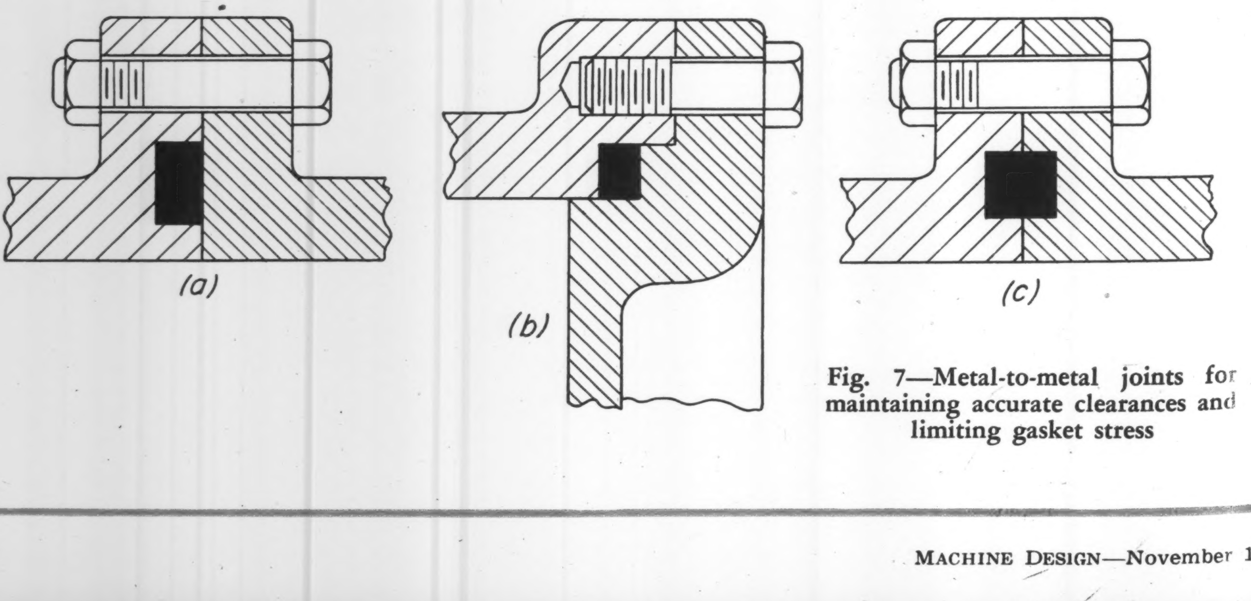


Fig. 7—Metal-to-metal joints for maintaining accurate clearances and limiting gasket stress

suitable for truly compressible materials such as cork composition and cork-and-rubber are shown in *Fig.* 7. However, these joints bear a great similarity to joints designed specifically for rubber O-rings. Rectangular-section rubber gaskets may be used thus if shape and volume are correct. Initial gasket volume must not exceed that of the cavity, but initial shape should be such that upwards of 25 per cent deflection of the rubber part occurs as the joint is closed. These joints are particularly good where it is essential to maintain accurate internal clearances or alignments. They are also useful for limiting the amount of stress on the gasket.

Self-energizing, or self-tightening, joints, *Fig.* 8, generally call for special molded shapes, although flat gaskets can be used in some cases. Rubber or plastic molded to special shapes are often used, *Fig.* 8*a*. A flat gasket for this purpose is shown in *Fig.* 8*b*.

Concentric joints, *Fig.* 9, require that the gasket exert its sealing force in a direction normal to the applied bolt stress. A deformable material which is relatively firm and incompressible works best. Rubber, for instance, deforms with minimum actual compression, although soft rubber is likely to extrude through clearances. Impregnated braided packings, cork-and-rubber, and straight rubber of 80 or 90 Shore hardness are especially worth considering. O-ring designs shown later are additional examples of concentric joints.

Threaded joints, *Fig.* 10, which close with torsion, require materials which are tough, inextensible and abrasion resistant. Hard compressed asbestos, leather and metal-jacketed gaskets are best. At least one of the mating surfaces should be smooth-finished to permit sliding against the gasket with minimum friction and abrasion.

Joints in which very simple gaskets have been adapted to gasket cavity designs of somewhat different shape are illustrated in *Fig.* 11. The possibilities in using simple round, square or flat cross-section gaskets should be exhausted before concluding that relatively expensive molded shapes are necessary.

For example, in *Fig.* 11*a* a square-section rubber ring is deformed in assembling a stamped container and cover. A flat rubber gasket is deformed to dish shape and held in place by steps or serrations in the sloping seat in *Fig.* 11*b*. This joint is between a ceramic insulator and a transformer cover. In *Fig.* 11*c* an open-head steel drum employs a rectangular-section cork-composition gasket or a hollow tubular rubber gasket.

General joint design suggestions for rubber O-rings are shown in *Fig.* 12; standards for packing and gasket installations in *Fig.* 13 and *Tables* 3

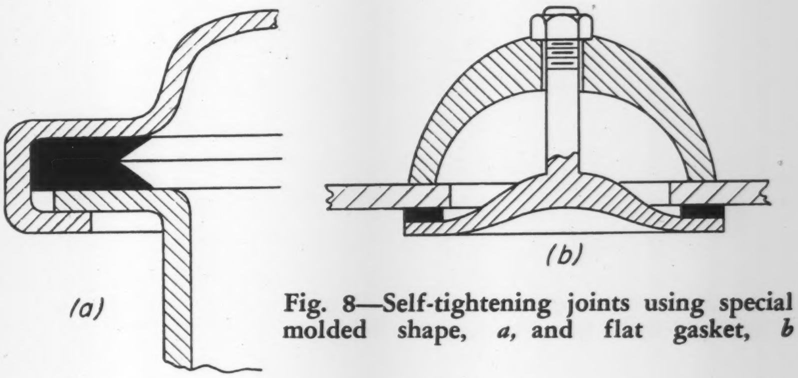


Fig. 8—Self-tightening joints using special molded shape, *a*, and flat gasket, *b*

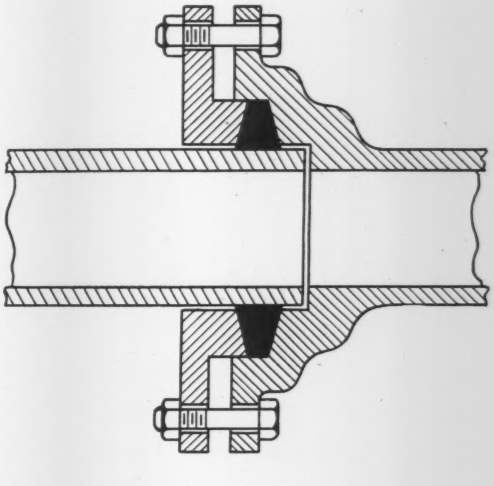


Fig. 9 — Concentric joint in which the gasket exerts sealing force normal to the applied stress

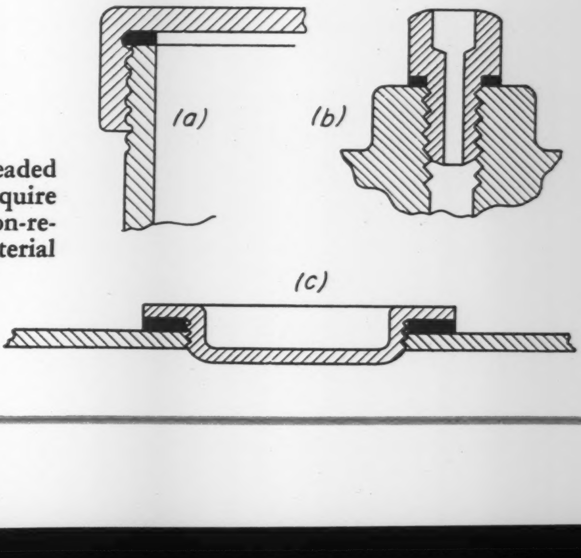


Fig. 10 — Threaded joints, which require a tough, abrasion-resistant gasket material

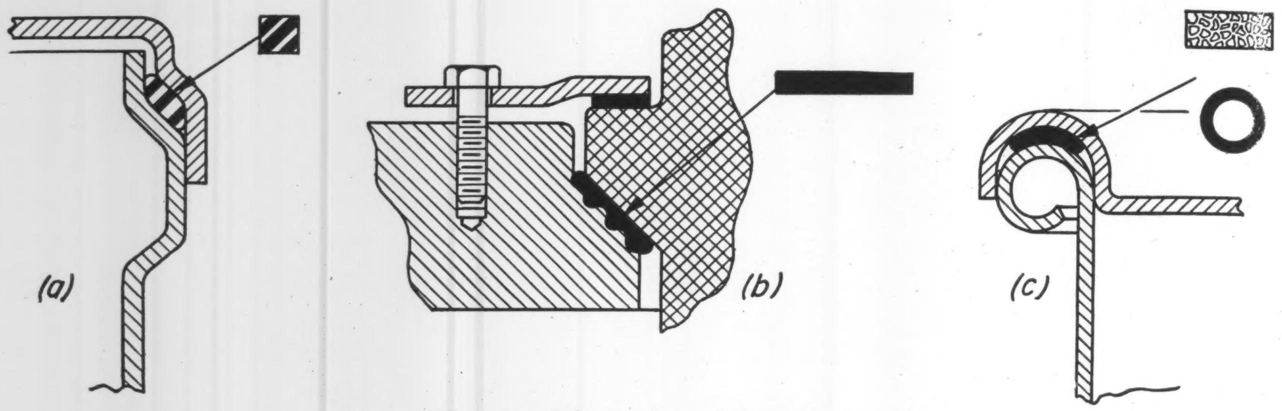


Fig. 11—Joints using gasket shape changes other than simple deflection

and 4; and static seal designs for O-rings in *Fig.* 14 and *Table* 5.

Bolt Stresses in Pressure Joints: Bolts or other fasteners used in pressure vessel assemblies perform several functions:

1. Prevent separation of gasket and flange due to action of internal fluid load.
2. Support additional stresses caused by gravity, misalignment, thermal expansion and contraction.
3. Develop gasket stresses equal to the fluid pressure, times a safety factor to counteract natural relaxation. This factor is the constant m in ASME formulas for bolted flanges.
4. Apply an initial yield or seating force to the gasket. This is independent of the confined pressure and is defined as the minimum stress that must be applied to the gasket to hold even a very low pressure. This is usually expressed in psi and is the constant y in ASME formulas. While it is treated there as a property of the gasket, it is to a great extent a measure of flange inaccuracies and varies with each joint.

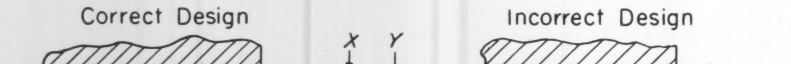


Fig. 12—General design suggestions for rubber O-rings

MEASUREMENT OF BOLT STRESSES: ASME rules for bolted flange connections provide means for determining required bolt loads for the operating and atmospheric conditions encountered, and also the required cross-section area of bolts, but they fail to provide means for determining how tight the bolt must be torqued in order to provide given loads and stresses. Unfortunately, there is no known method for determining this load accurately under usual shop conditions, but several methods of estimating such forces have been developed:

1. *Estimate load* from the formula $W = 16{,}000d$ where W = initial load due to screwing up, pounds; and d = nominal OD of screw thread, inches. This equation was developed experimentally as an indication of the load applied on the average by experienced mechanics. (For additional details, see ***Elements of Machine Design,*** Kimball and Barr, third edition.)

2. *Specify torque-wrench settings* in conjunction with ***Tables*** 6 and 7. The following qualifications apply in the use of these data:

   a. Bolts must be as described in the tables.
   b. Bolts must be well lubricated, preferably with oil and graphite. Nonlubricated bolts may rate only 50 per cent as efficient.
   c. Care must be exercised that gasket clears bolt threads and does not flow into them, creating extra torsional resistance.

3. *Measure bolt elongation* and, from estimated modulus of elasticity, calculate bolt stress.

4. *Compute bolt stress* from screw formulas. Remember, however, that refined calculations are considered useless and misleading by many authorities, especially for fastenings less than ⅞-inch diameter.

Stresses in Low-Pressure Joints: ASME formulas referred to previously have been developed from research dealing specifically with pipe joints for which standard flange sizes and designs and standard bolting specifications are available. They also concern gaskets which lie wholly inside the bolt circle. Many of the principles indicated are adaptable to gasketing in general but, for normal work with joints and covers of the many kinds that are found in factory assembled mechanisms, a somewhat different approach is indicated.

The function of bolts, screws, or other fasteners is to bring about optimum or required deflection of the gasket. Different gasket materials require or tolerate quite different compressive stresses, but for purposes of this discussion they can be broadly classified as: (1) the easily deformed, truly compressible types such as cork compositions and cork-and-rubber compounds, (2) incompressible compounds of rubber and rubber-like materials, and (3) fiber sheet packings.

EASILY COMPRESSED MATERIALS: General form of load-compression curves for these materials is as shown in *Fig*. 15 where points *A* and *B* have been located schematically. The part of the curve below point *A* involves pressures which are too low to be of any value in forming and maintaining a good seal, whereas above point *B* the material has been compressed nearly to its ultimate density. Forces higher than those represented by *B* are not only uneconomic in relation to additional compression produced but may produce some form of creep or internal rupture, manifested as excessive compression set.

Suggested compression range for soft gasketing is between points *A* and *B* where pressures are adequate to promote good contact of gasket to adjacent surfaces, but are still within the range where stress and strain are roughly proportional.

For typical materials within this classification, recommended deflections are as given in *Table* 8. The estimated loads to produce deflections within the recommended range must be used as a very general guide since they are affected by numerous variables, including temperature, rate of application of load, production tolerances in the materials under con-

Table 3—Standards for O-Rings*

O-Ring Specification Dash No.	O-Ring Section Diam	Diametral —Squeeze, min— Moving	Diametral —Squeeze, min— Static	*C* —Gland Width— Moving†	*C* —Gland Width— Static§	*D* Groove Length	*R* Radius, min	*2E* Diametral Clearance, max
AN-6227								
1 to 7	0.070±0.003	0.010	0.015	0.057	0.052	3/32	1/64	0.005
8 to 14	0.103±0.003	0.010	0.017	0.090	0.083	9/64	1/64	0.005
15 to 27	0.139±0.004	0.012	0.022	0.123	0.113	3/16	1/32	0.006
28 to 52	0.210±0.005	0.017	0.032	0.188	0.173	9/32	3/64	0.007
53 to 88	0.275±0.006	0.029	0.049	0.240	0.220	3/8	1/16	0.008
AN-6230 Gaskets								
1 to 52	0.139±0.004	....	0.022	....	0.113	3/16	1/32	0.006

All dimensions in inches. *See *Fig*. 13 for explanation of dimensions. †Tolerance: +0.000, −0.001. §Tolerance: +0.000, −0.005.

Table 4—O-Ring Standards Using Backup Rings*

O-Ring Specification Dash No.	*D* Moving Seal Groove Length† 2 Rings	*D* Moving Seal Groove Length† 1 Ring	*D* Static Seal Groove Length† 2 Rings	*D* Static Seal Groove Length† 1 Ring
AN-6227				
1 to 7	0.206	0.139	0.211	0.144
8 to 14	0.238	0.171	0.245	0.178
15 to 27	0.275	0.208	0.285	0.218
28 to 52	0.410	0.311	0.425	0.326
53 to 88	0.538	0.408	0.558	0.428
AN-6230 Gaskets				
1 to 52	....	....	0.285	0.218

All dimensions in inches. *AN-6246 backup (nonextrusion rings); see *Fig*. 13 for explanation of dimensions; for other dimensions see *Table* 3. †Tolerance: +0.005, −0.000.

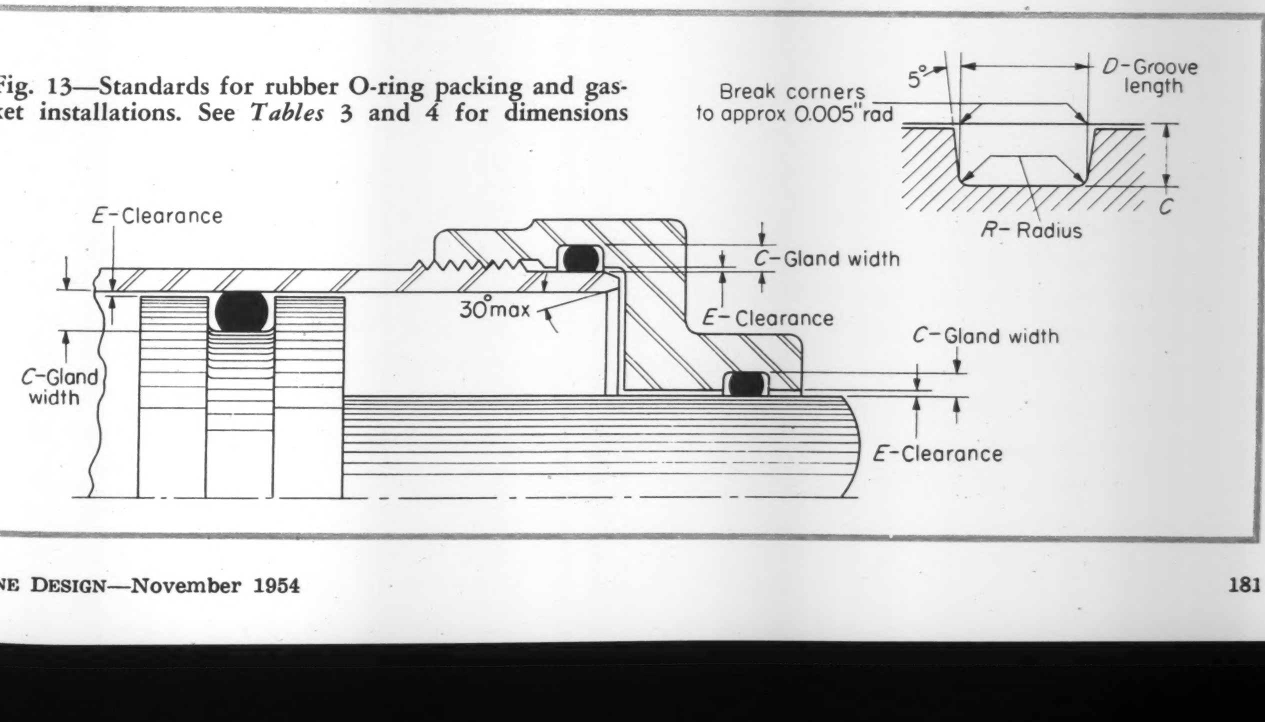


Fig. 13—Standards for rubber O-ring packing and gasket installations. See *Tables* 3 and 4 for dimensions

sideration, and character of flange finish.

STRAIGHT RUBBER COMPOUNDS: Load-deflection characteristics of parts cut from sheet rubber will be highly variable according to width and thickness of the gasket, character of the flange finish, lubricant present on the contact surfaces, Durometer hardness and modulus of the particular stock, temperature, and rate and method of load application. The problem is to apply enough pressure to seal the joint without loading so heavily as to overstress the rubber or cause excessive extrusion.

A general recommendation which may be followed is: For flat gaskets cut from a 60-Durometer (Shore type A) sheet rubber, figure 500 to 1000 psi on the area of the gasket. Decrease for softer rubbers, increase for harder compounds; but do not exceed 25 per cent deflection.

FIBER SHEET PACKINGS: Because of their relative firmness, fiber sheet materials generally require heavy pressures to cause adequate yielding for initial intimate contact. Many of them also develop impermeability by being compressed. Therefore, the problem is usually one of applying adequate load rather than being careful not to overload.

Cellulose-fiber materials in general require less flange pressure to effect a seal than asbestos-rubber types and are generally to be preferred in light-duty applications where constant operating temperatures do not exceed 160 F, and where environmental conditions are not detrimental to cellulose.

Suggested minimum loadings for fiber gaskets not required to hold fluid pressures are: vegetable fiber, 500 psi; compressed asbestos and other hard sheets, 1000 psi.

Bolt Spacing: In pressure vessels, bolt spacing (pitch) may vary from 7 times the bolt diameter for installations in which pressure is not over 50 psi to 3.5 times bolt diameter for installations in which pressure is 200 psi. Closer spacing must take into consideration the limiting factor of required wrench openings.

In low-pressure joints employing soft gaskets, bolt spacing need only follow considerations of properly distributing the flange pressure for reasonable equality over the face of the gasket. By ingenious design incorporating ribs and corrugations for extra rigidity of the metal members, a surprising degree of uniformity of contact pressure can be obtained in assemblies where the bolts are spaced very far apart.

Surface Finish: In joints designed for flat gaskets, some roughness is good. It helps keep the gasket from extruding or sliding out of the joint. A surface finish of 250 microinches, is suggested as a good practical finish for ordinary gasket applications.

Waviness and warping in flanges is objectionable if the joint is a heavy-duty one, but may be tolerated in nonpressure applications by the selection of soft, compressible gasket materials.

In O-ring joints, the gasket cavity must be very smoothly finished. The type of finish commonly known as superfinish is considered satisfactory, although in many installations the contact surfaces are chromium plated.

Gasket Thickness: Ultimate compressibility of the gasket must ex-

Table 5—O-Ring Static Seal Designs*

O-Ring Specification Dash No.	O-Ring Section Diam	Sketch a: A Groove Width†	Sketch a: A (max) Groove Width	Sketch a: B Groove Depth	Sketch a: R Radius, max	Sketch b: C Depth§	Sketch b: D Width
AN-6227							
1 to 7	0.070±0.003	0.057	0.062	0.056	0.005	0.052	3/32
8 to 14	0.103±0.003	0.085	0.090	0.083	0.010	0.083	9/64
15 to 27	0.139±0.004	0.114	0.119	0.113	0.010	0.113	3/16
28 to 52	0.210±0.005	0.168	0.173	0.173	0.015	0.173	9/32
53 to 88	0.275±0.006	0.226	0.231	0.220	0.015	0.220	3/8
AN-6230 Gaskets							
1 to 52	0.139±0.004	0.114	0.119	0.113	0.010	0.113	3/16

All dimensions in inches. *See *Fig.* 14 for explanation of symbols. †To sharp corners. §Tolerances: +0.000, —0.005.

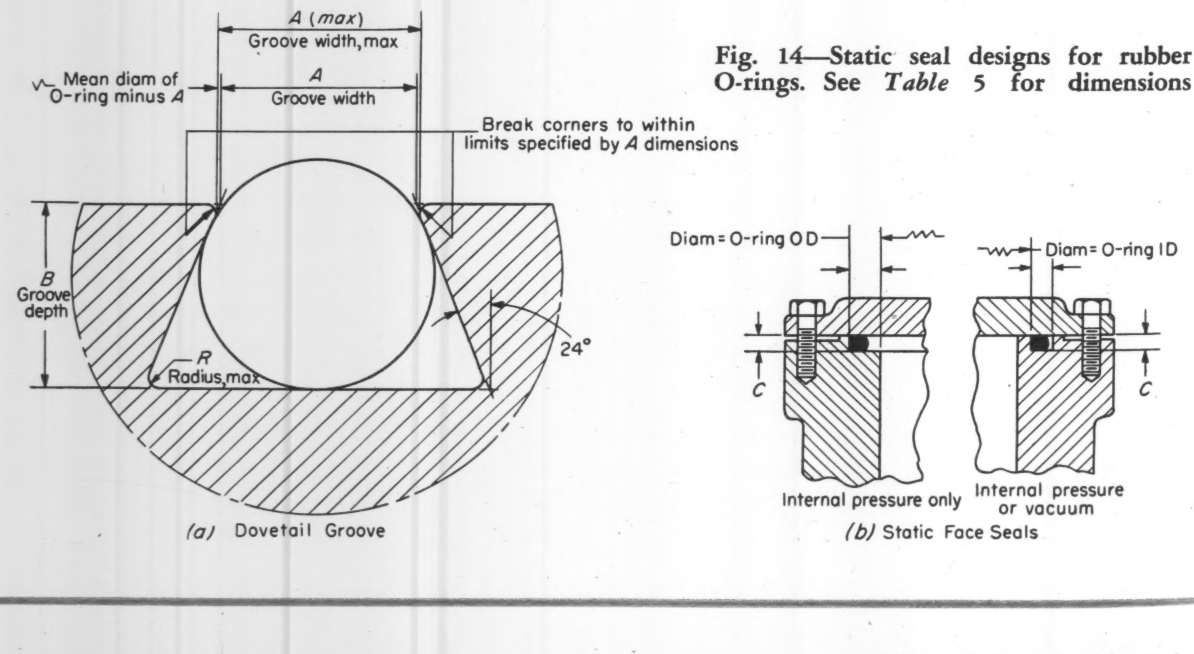


Fig. 14—Static seal designs for rubber O-rings. See *Table* 5 for dimensions

ceed the cumulative deviation of the two flange surfaces from perfect parallelism. For example, a commercial compressed-asbestos gasket ⅛-inch thick can be compressed only about 0.020-inch; if cumulative inaccuracies approach this amount, the joint cannot be sealed with ⅛-inch compressed-asbestos. Alternatives would be to consider the use of a still thicker compressed-asbestos gasket (which in most cases would be rather impractical) or the use of a softer, more yielding gasket.

Subject to the requirement just stated, gasket thickness is generally determined by rule of thumb: Use the thinnest gasket that will pack the joint. Since considerable leeway generally exists in the choice of gasket thickness, a standard or commercial thickness should be specified for reasons of economy and to facilitate procurement.

Practical Gasket Tolerances: Uninformed draftsmanship often results in specification of soft gaskets to metalworking tolerances. It is futile to expect to obtain nonmetallic gaskets to such tolerances, because:

1. The ability to be deformed under pressure, the property that really makes a material valuable for use as a gasket, also prevents a material from being processed commercially with the same precision as a rigid material. It yields under the pressure from tools, knives, wheels, or cutters.
2. The characteristic of easy deformability offers the further complication that gaskets cannot be measured uniformly by different people using different types of equipment. Therefore, tolerances must reflect not only the vendor's processing variations but also the probability that the user may inspect by different equipment and techniques than did the vendor.
3. Nearly all gasket materials show some response to temperature and humidity variations. Such atmospheric variations may affect both the hardness and dimensions of the gasket and, therefore, comparison is possible only if standard conditioning is prescribed for a suitable length of time prior to gaging. Even so, dimensional changes of a permanent type may occur with certain materials.

Commercial tolerances on most nonmetallic gaskets and gasket materials will range approximately as follows:

Thickness: Materials which are made by rolling or calendering or by paper-making processes, ± 10 per cent. Soft materials sliced or split from thicker sheets or blocks, ± 0.010 to ± 0.020-inch, depending on thickness.

Length, width, and spacing dimensions: ± 0.010 to ± 0.031-inch.

Diameters: Bolt holes, gasket and washer OD's and ID's, ± 0.010 to ± 0.020-inch.

This information on tolerances is for general guidance only. Individual vendors state tolerances applicable to their shops and products. In general, variation within a single gasket will be 50 per cent or less of the over-all variation specified for the lot. That is, the gasket vendor who wants tolerances of ± 0.015-inch over-all on thickness may be willing to accept a supplementary specification calling for a maximum variation of 0.010 or 0.015-inch in any one gasket.

Inspection of mass-produced gaskets is generally by some scientific sampling method, using tables corresponding to 2 to 10 per cent lot tolerance per cent defective, depending upon the type of material and end use. Gaskets produced for assembly-line use are generally purchased at a price which precludes any considerable cost of inspection. However, gasket producers will gen-

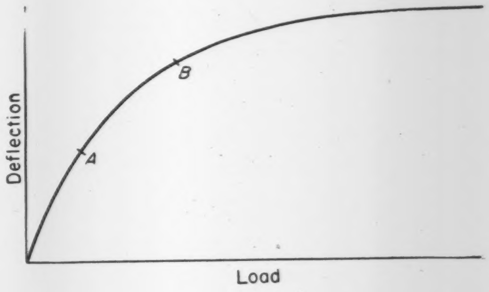


Fig. 15—Typical load-deflection curve for "soft" gasket materials

Table 6—Machine and Cold-Rolled Steel Bolt Stud Loads*

Bolt Nominal Diam (in.)	Threads per Inch	Thread Root Diam (in.)	Thread Root Area (in.²)	For 7500 psi Bolt Stress Torque (lb-ft)	For 7500 psi Bolt Stress Compression (lb)	For 15,000 psi Bolt Stress Torque (lb-ft)	For 15,000 psi Bolt Stress Compression (lb)	For 30,000 psi Bolt Stress Torque (lb-ft)	For 30,000 psi Bolt Stress Compression (lb)
¼	20	0.185	0.027	1	203	2	405	4	810
5/16	18	0.240	0.045	2	388	4	675	8	1 350
⅜	16	0.294	0.068	3	510	6	1 020	12	2 040
7/16	14	0.345	0.093	5	698	10	1 395	20	2 790
½	13	0.400	0.126	8	945	15	1 890	30	3 780
9/16	12	0.454	0.162	12	1 215	23	2 430	45	4 860
⅝	11	0.507	0.202	15	1 515	30	3 030	60	6 060
¾	10	0.620	0.302	25	2 265	50	4 530	100	9 060
⅞	9	0.731	0.419	40	3 143	80	6 285	160	12 570
1	8	0.838	0.551	62	4 133	123	8 265	245	16 530
1⅛	7	0.939	0.693	98	5 190	195	10 380	390	20 760
1¼	7	1.064	0.890	137	6 675	273	13 350	545	26 700
1⅜	6	1.158	1.054	183	7 905	365	15 810	730	31 620
1½	6	1.283	1.294	219	9 705	437	19 410	875	38 820
1⅝	5½	1.389	1.515	300	11 363	600	22 725	1 200	45 450
1¾	5	1.490	1.744	390	13 080	775	26 160	1 550	52 320
1⅞	5	1.615	2.049	525	15 368	1 050	30 735	2 100	61 470
2	4½	1.711	2.300	563	17 250	1 125	34 500	2 250	69 000

*Data, courtesy Crane Co.

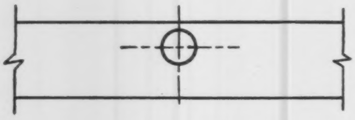
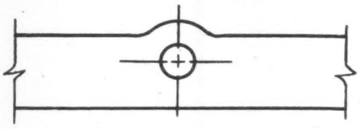
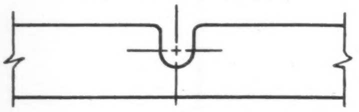
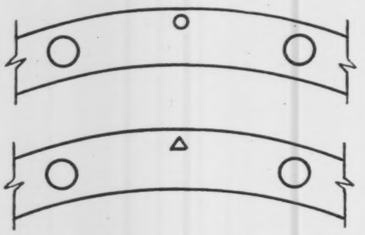
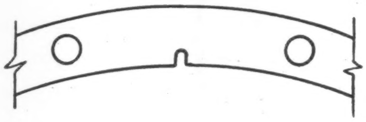
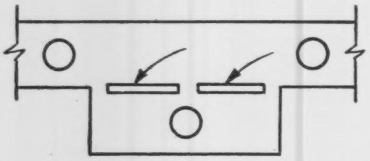
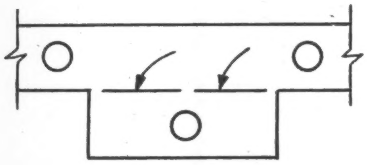
Detail	***Why Faulty***	***Suggested Remedy***
Bolt holes close to edge 	Causes breakage in stripping and assembling	Projection or "ear"  Notch instead of hole 
Very small bolt holes or noncircular openings 	Require hand picking easy to miss	Avoid hole sizes under 3/32-inch diameter. If small hole is for locating or indexing, change to notch 
Tear-away parts with open slots at attached edges 	Slots require hand picking; costly dies and die maintenance	Simple perforation 

Table 7—Alloy Steel Bolt Stud Loads*

Stud Nominal Diam	Threads per Inch	Thread Root Diam (in.)	Thread Root Area (in.^{2})	For 30,000 psi Bolt Stress		For 45,000 psi Bolt Stress		For 60,000 psi Bolt Stress	
				Torque (lb-ft)	Compression (lb)	Torque (lb-ft)	Compression (lb)	Torque (lb-ft)	Compression (lb)
¼	20	0.185	0.027	4	810	6	1 215	8	1 620
5/16	18	0.240	0.045	8	1 350	12	2 025	16	2 700
⅜	16	0.294	0.068	12	2 040	18	3 060	24	4 080
7/16	14	0.345	0.093	20	2 790	30	4 185	40	5 580
½	13	0.400	0.126	30	3 780	45	5 670	60	7 560
9/16	12	0.454	0.162	45	4 860	68	7 290	90	9 720
⅝	11	0.507	0.202	60	6 060	90	9 090	120	12 120
¾	10	0.620	0.302	100	9 060	150	13 590	200	18 120
⅞	9	0.731	0.419	160	12 570	240	18 855	320	25 140
1	8	0.838	0.551	245	16 530	368	24 795	490	33 060
1⅛	8	0.963	0.728	355	21 840	533	32,760	710	43 680
1¼	8	1.088	0.929	500	27 870	750	41 805	1 000	55 740
1⅜	8	1.213	1.155	680	34 650	1 020	51 975	1 360	69 300
1½	8	1.338	1.405	800	42 150	1 200	63 225	1 600	84 300
1⅝	8	1.463	1.680	1 100	50 400	1 650	75 600	2 200	100 800
1¾	8	1.588	1.980	1 500	59 400	2 250	89 100	3 000	118 800
1⅞	8	1.713	2.304	2 000	69 120	3 000	103 680	4 000	138 240
2	8	1.838	2.652	2 200	79 560	3 300	119 340	4 400	159 120
2¼	8	2.088	3.423	3 180	102 690	4 770	154 035	6 360	205 380
2½	8	2.338	4.292	4 400	128 760	6 600	193 140	8 800	257 520
2¾	8	2.588	5.259	5 920	157 770	8 880	236 655	11 840	315 540
3	8	2.838	6.324	7 720	189 720	11 580	284 580	15 440	379 440

*Data, courtesy Crane Co.

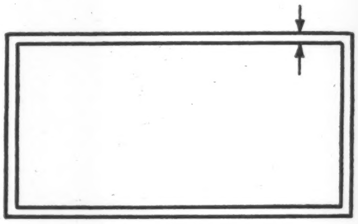
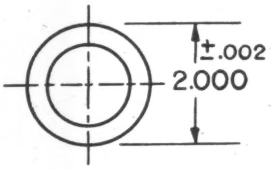
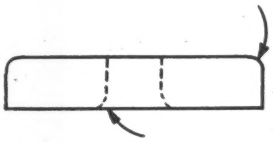
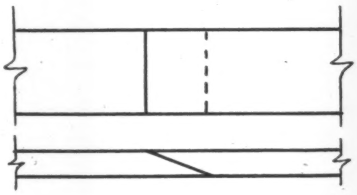
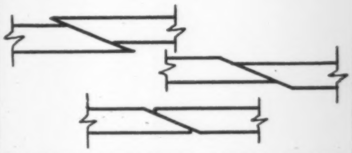
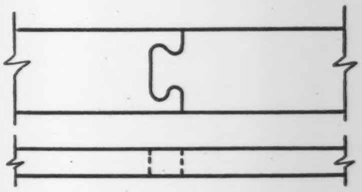
Detail	Why Faulty	Suggested Remedy
Thin walls, delicate cross section in relation to over-all size 	High scrap loss; stretching or distortion in shipment or use. Restricts choice to high tensile strength materials	Have the gasket in mind during early design stages
Metalworking tolerances applied to gasket thickness, diameters, length width, etc. 	Results in perfectly useable parts being rejected at incoming inspection. Requires time and correspondence to reach agreement on practical limits. Increases cost of parts and tooling. Delays deliveries.	Most gasket materials are compressible. Many are affected by humidity changes. Try standard or commercial tolerances before concluding that special accuracy is required
Transference of fillets, radii, etc., from mating metal parts to gasket 	Unless part is molded, such features mean extra operations and higher cost.	Most gasket stocks will conform to mating parts without preshaping. Be sure radii, chamfers, etc., are functional, not merely copied from metal members
Large gaskets made in sections with beveled joints 	Extra operations to skive. Extra operations to glue. Difficult to obtain smooth, even joints without steps or transverse grooves. 	Die-cut dovetail joint 

Fig. 16—Common faults in gasket design

Table 8—Compression Ranges and Loads for "Soft" Gaskets

Material	Specifications		Recommended Compression (per cent)	Estimated Load (psi)
Cork composition	MIL-C-16090	MIL-G-12803 (ORD)		
	Class 1	G-2111, G-2211	40–60	100
	Class 2	G-2112, G-2212	35–55	125
	Class 3	G-2113, G-2213	30–50	150
	Class 4	G-2114, G-2214	20–40	200
Cork-and-rubber	MIL-G-6183	MIL-G-12803 (ORD)		
	Types I & II, Soft	G-1222-4, G-1223-4	25–40	175
	Types I & II, Med.	G-1222-3, G-1223-3	20–35	225
	Types I & II, Firm	G-1222-2, G-1223-2	15–25	400

erally agree to supply closer than commercial tolerances and special inspection at extra cost and by specific agreement. The purchaser should be sure that such noncommercial standards are required and are not an indication of a design defect which should be corrected by means other than the imposition of special tolerances on the gasket.

Assembly-Line Design: Conditions

prevailing on a rapidly moving assembly line frequently call for features which are of no interest or importance to the small-lot user. Such features are:

1. For rapid handling, select a stiff gasket in preference to a floppy one, less easy to place in position.

2. Gaskets which are almost, but not quite, symmetrical should be provided with an index notch or other feature to signal the proper position relative to adjacent parts.

3. Very large gaskets may be easier to handle if brought to the job in sections with interlocking ends rather than in one solid piece. Also, if the bolt holes are made elongated instead of perfectly round, such gaskets will go in place faster.

4. Where character of fit is critical (that is, avoiding a too-loose or too-tight fit), it is a good idea to provide the gasket manufacturer with an approved part or assortment of parts to which he can fit the gasket. Due to differences in measuring techniques and equipment, merely following a blueprint will not guarantee that the gasket will fit the part in the manner desired.

5. Avoid having lubricants and wet adhesives on any flanges where slipping can occur, or use gaskets which do not slip on oily surfaces.

Common Errors: Gasket design details which may give the fabricator trouble or which may lead to disappointing results in service are shown in *Fig.* 16, along with suggestions for avoiding these faults.

SPECIFICATIONS AND TESTING

GASKET specifications are designed to give the gasket user a control instrument whereby he can derive reasonable assurance of receiving successive lots of an item alike in quality, and suitable for the intended purpose. Thus, a double concept is introduced—quality control and performance.

> **A quality control specification** describes physical characteristics which are used to specify a material which has been demonstrated historically to suit the application involved.
>
> **A performance specification** is intended to pass any kind of product that performs the required functions in accordance with minimum specified efficiency and durability.

The idea of an end-use specification based on performance tests is very attractive and certainly something that every user of gasket materials would like to have available. However, this ideal is seldom realized, and gasket specifications tend to be simple control instruments, since:

> 1. A performance specification must be written around a very narrow and specific set of reproducible service conditions, whereas the possible combinations of gasket service conditions are infinite.
>
> 2. Attempts to accelerate actual service conditions in a so-called performance test have resulted in the addition of further complications.

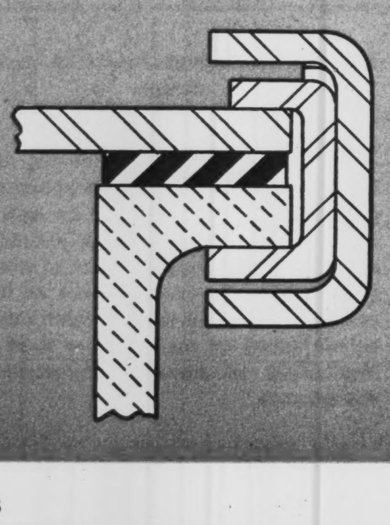
Even with these points in mind, it is difficult for most people to disassociate the idea of performance from specification figures. This introduces certain misconceptions and abuses. For instance, there is the idea that because one material does not meet the control standards written around another product it must be inferior. Actually, the reverse could be true.

Progress in the development of new products tends to be impeded, since there is the temptation to the manufacturer to devote his research to the development of products which will pass existing specifications rather than to the development of new products which will perform better in service.

Reverence for specification values may result in the use of tests peculiar to a given industry, but which have little relation to end use of the product. For example, paper gasket specifications sometimes incorporate ream weight and Mullen burst requirements which are recognized as good tests in the paper industry, but which when carried over to gaskets have little apparent application.

Testing Procedures and Evaluation: The subject of testing gasket materials is involved because of the variety of available materials and the galaxy of service conditions and combinations thereof which must be met. The objective is to develop a service type test which would indicate in a short time whether a given material would stand up under certain conditions. This goal has rarely been attained, even for comparatively simple applications. The current practice is to draw conclusions from the results of various fundamental physical measurements, supplemented by simulated service (or "practical") tests designed to duplicate the usage in an accelerated fashion. These last often do not work properly because of the attempt at acceleration.

Most gasket materials are sold on specifications which prescribe the physical and chemical properties sufficiently to insure that the purchase of a specified material which has been demonstrated historically as able to provide a satisfactory seal under certain conditions. These specifications include certain tests of funda-



Watt-Hour Meter

Soft enough to take up irregularities in the glass cover and die-cast meter base, the gasket used in this watt-hour meter must also withstand abrasion caused by turning the cover into usual attachment slots. The cork-and-rubber (neoprene) gasket is compressible, and is treated to reduce surface friction and abrasion.

mental properties:

1. Density
2. Tensile strength
3. Compression and recovery
4. Dimensional change
5. Flexibility
6. Resistance to liquids

Additional tests have been designed which either give values which supplement the fundamentals listed previously or are variations:

Tensile strength after exposure to heat, dry atmospheres, wet atmospheres, and/or various liquids. Usually after reconditioning.

Wet tensile strength immediately after removal from immersion in various liquids.

Tearing resistance by various recognized methods.

Bursting strength—Mullen.

Porosity — measurement of the passage through the material (perpendicular to the plane of the sheet) of gases or liquids.

Dimensional and weight change after exposure to various atmospheric conditions in different combinations, and to various liquids.

Hardness by indentation, Shore Durometer, Pusey & Jones Plastometer, or other devices.

Moisture content as received or in conjunction with dimensional change tests.

Compressibility — load-compression-recovery characteristics with wide range of loads and times.

Compression set (permanent set) by ASTM method A—constant load; or B—constant deflection.

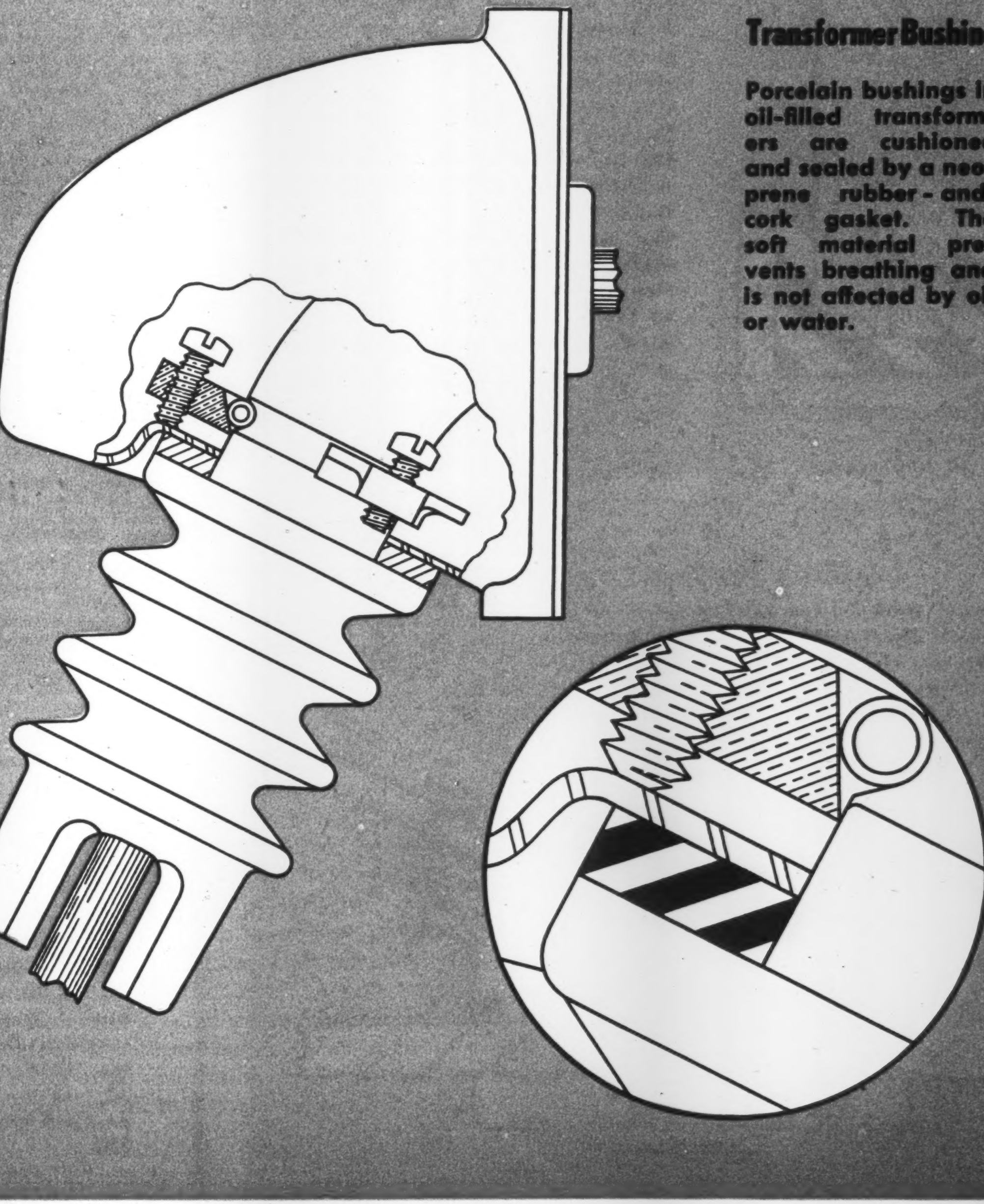
Wicking action—with one end of a strip immersed in liquid, measurement of the rate of rise of the liquid.

Coefficient of static friction by observing the angle at which the sample slides on an incline plane, or by measuring the force required to move the sample on a horizontal plane. With various surfaces and pressures.

Coefficient of static friction between flange plates under compression.

Service tests developed by manufacturers and users are essentially the subjection of a gasket at controlled compression to the action of a gas or liquid at controlled pressure, temperature and flow. If these yield satisfactory data it is usually because they duplicate the service condition in almost every particular including time. Since leakage of gaskets is a complicated affair, attempts at making them leak quickly do not agree very well with results obtained in practice.

While there are several experi-

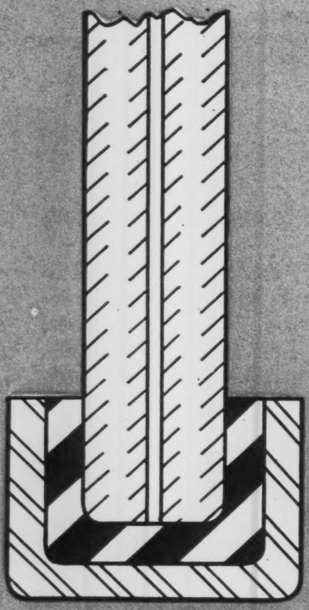


Transformer Bushing

Porcelain bushings in oil-filled transformers are cushioned and sealed by a neoprene rubber-and-cork gasket. The soft material prevents breathing and is not affected by oil or water.

mental developments being carried on by various laboratories to develop a technique for measuring stress relaxation or gasket "kick-back," the only satisfactory method for use under field and shop conditions is the measurement of torque loss.

General procedure is to screw up on the bolts with a torque wrench to a specified reading, and then subject the assembly to a certain set of conditions for a specified time. The breakaway torque is then measured and compared with the original torque. Quite a case could be made for the inherent inaccuracies of such determinations, but as a practical means of quickly and easily getting some idea of relative properties, and under production-line conditions, there is little that can be said against this procedure. Experienced observers, however, will refrain from concluding that excessive torque loss must necessarily and definitely be attributed to the gasket. Other causes can be involved, such as relaxation in the bolts and flanges, or differential response to temperature changes.

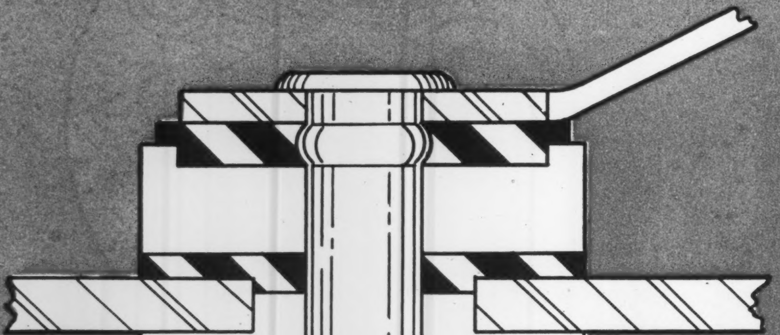


Transportation Sashes

To hold glass in its frame, a gasket material with high coefficient of friction and extreme resilience is needed. A soft neoprene and cork composition produced on a fabric backing is used. The backing is coated with latex adhesive, protected by Holland cloth. To apply the gasket, the Holland cloth is stripped off, and the coated side is pressed to the surface to be covered.

Condenser Terminals

These washers for fixed-condenser terminals must seal tightly even between off-true surfaces. High electrical resistance is supplied by a cork and neoprene composition, and the gasket is also resistant to oil and moisture.



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EXTRA COPIES

Extra copies of "Nonmetallic Gaskets," bound as a 32-page brochure, are available for $1.00 each from: Reader Service Dept., *Machine Design,* Penton Bldg., Cleveland 13, Ohio. Also see postcard opposite Page 220.

Applying Magnetic-Particle Clutches and Brakes

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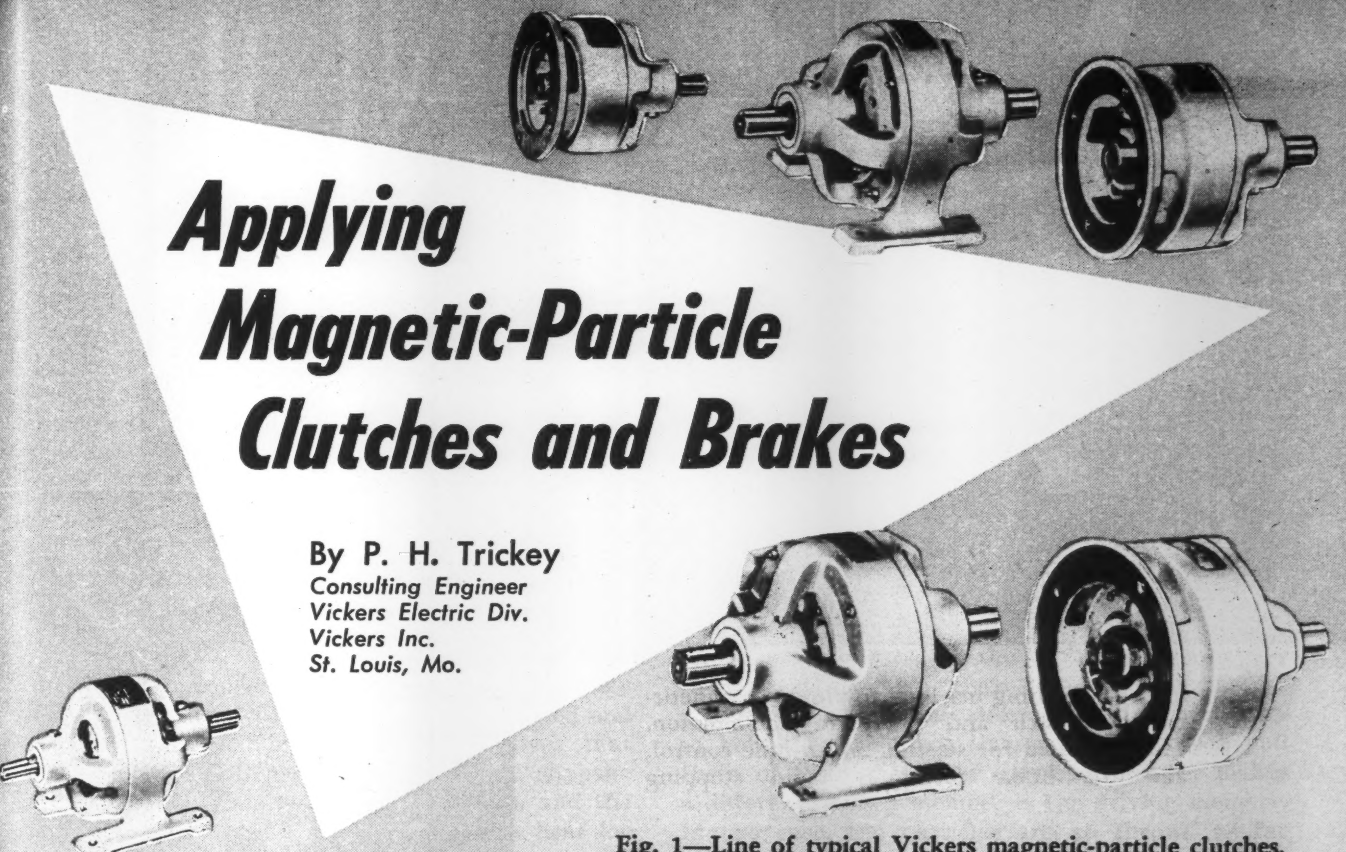


Fig. 1—Line of typical Vickers magnetic-particle clutches. Rated torque capacities of these Magneclutch magnetic-particle clutches cover a range from 10 to 200 lb-ft

MORE than six years have passed since research reports on the magnetic-particle clutch were first released. During that period, development progress on this new type of clutch has followed a pattern common to most inventions. Numerous designs have been produced and put into service in a variety of different applications, both military and commercial. Such field experience has borne out early predictions of smooth operation, long life and other advantageous performance characteristics.

A typical line of clutches for foot mounting and flange mounting is shown in *Fig.* 1. The small brake shown in *Fig.* 2 is used in tapping machines. Application of this small magnetic-particle brake on a winding machine, in combination with a magnetic-particle clutch, is illustrated in *Fig.* 3.

Application problems have been fewer than would be expected in a product of this type. Difficulties encountered have been, primarily, ones of applying the clutch in particular types of service. This experience points up the fact that the magnetic-particle clutch can offer certain advantages over other clutching devices, but only when properly applied. To obtain optimum performance in any given application, certain basic factors must be considered.

Torque: In principle, the magnetic-particle clutch

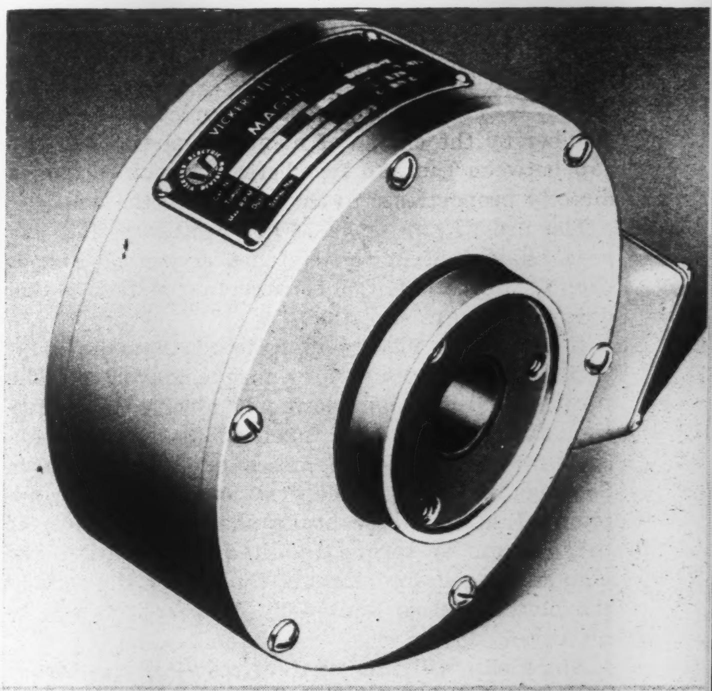


Fig. 2—Magnebrake magnetic-particle brake for use on tapping machines. Rated braking torque capacity is 25 lb-ft

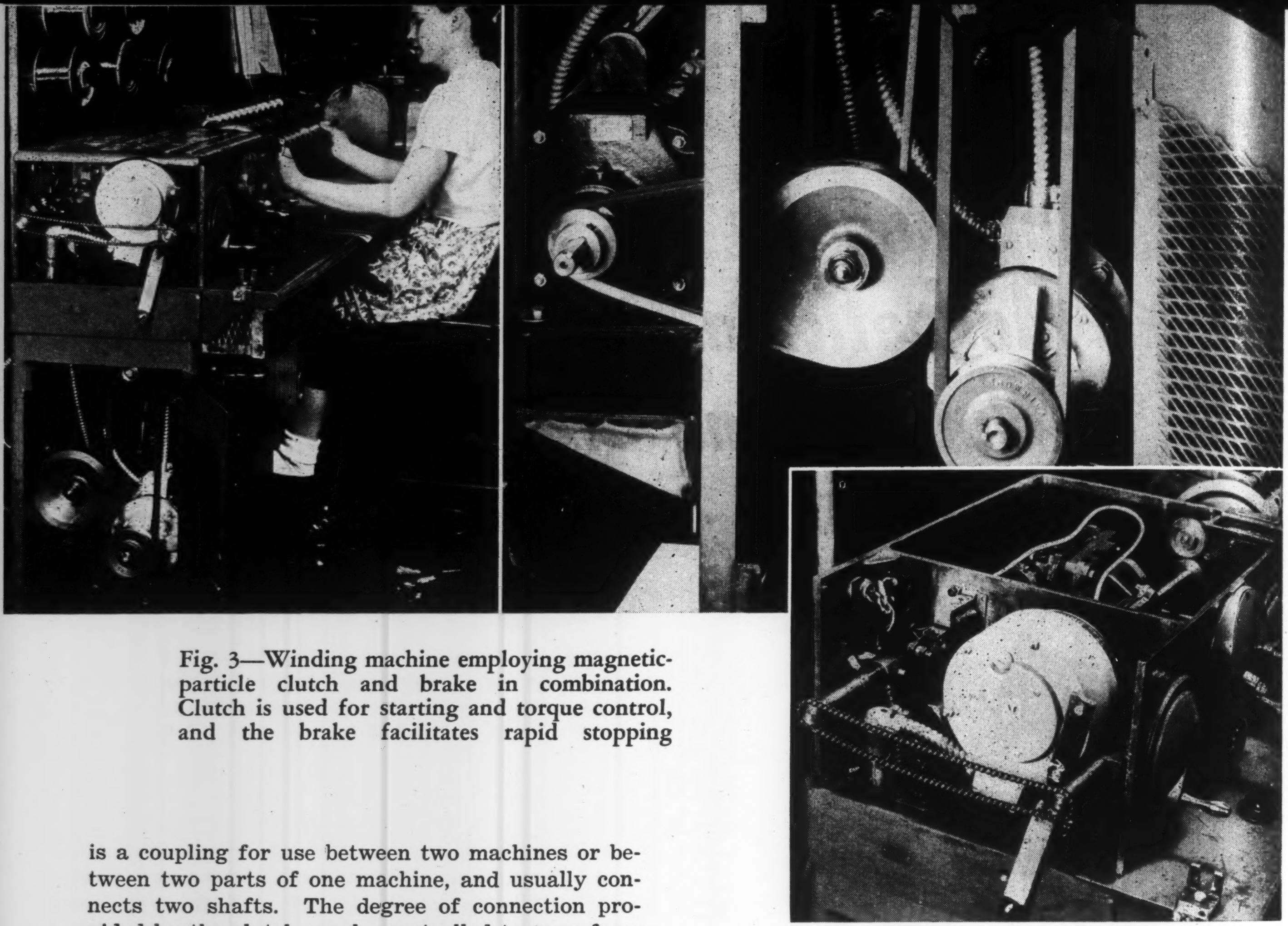


Fig. 3—Winding machine employing magnetic-particle clutch and brake in combination. Clutch is used for starting and torque control, and the brake facilitates rapid stopping

is a coupling for use between two machines or between two parts of one machine, and usually connects two shafts. The degree of connection provided by the clutch can be controlled to vary from a firm connection to complete disconnection. This degree of connection, which determines the torque transmitted by the coupling, is a function of the magnetic flux generated regardless of whether the two coupled parts are stationary or rotating.

A clutch construction using slip rings is shown in *Fig.* 4. The inner member is coupled to the outer member by the chains of magnetic particles in the gap between the two members. Output torque is directly proportional to the current in the coil.

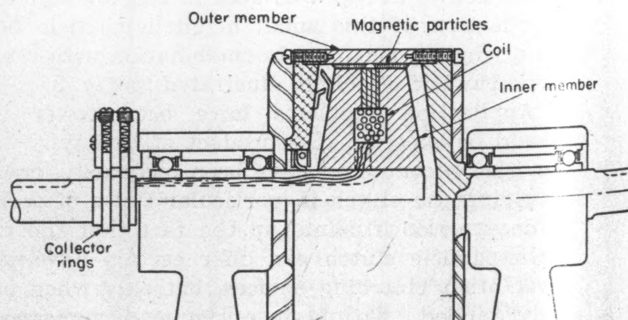
The use of slip rings is not necessary and has been eliminated in the clutches shown in *Fig.* 1. *Fig.* 5 shows a patented construction method which does not require slip rings.

It should be clearly understood that the magnetic-particle clutch is not a torque converter. The torque applied at one shaft will always be exactly the same as the torque taken off at the other, except for the negligible losses due to friction in bearings and seals. The first consideration in applying this clutch or brake should, therefore, be the amount of torque required. The larger the amount of required torque, the larger the size of the clutch, unless limited by heat loss as will be discussed later.

Since slip will immediately result if the torque of the clutch is exceeded, it is important to carefully consider any overload that may be expected. Electric motors, for example, will carry more than double load for a short time. If an electric motor is driving a load through a magnetic-particle clutch, the clutch may be required to carry any torque the motor will carry, perhaps up to 2½ times full-load torque.

As shown in *Fig.* 6, the torque transmitted is essentially proportional to the coil current and will vary when the current is changed. Thus, if the voltage is low, the torque will be low. Also, the

Fig. 4—Typical magnetic-particle clutch construction employing slip rings for electrical connection with dc coil power source



resistance of the coil will be lower when the coil is cool than when the clutch has attained normal operating temperature. Clutches usually are designed to carry their load on 90 per cent voltage, with the unit operating at full-load-rated temperature rise. The direct-current supply for the coil is often obtained through use of a transformer and rectifier. It is important that voltage drops through such devices are not overlooked.

As previously mentioned, the magnetic-particle clutch will slip when the rated torque is exceeded. Proper allowance must be made to meet all required overload conditions. For some applications, however, it is preferred that the clutch does not carry an overload. Many clutches are applied for the specific purpose of limiting the amount of torque which can be applied to the load or taken from the motor. The aim is to eliminate the danger of burning out a motor due to overloading, or to protect a product or a machine from breakage due to excess torque or a jammed load.

In such applications, the clutch slips harmlessly while the cause of the stoppage is determined and corrected. It must be remembered, however, that even though no other damage will result, slippage for too long a time will cause heat loss, and the clutch must be capable of dissipating this heat for a period of time sufficient to permit correction of the trouble. This aspect will be discussed more fully later.

Speed: Torque transmitted by a magnetic-particle clutch is essentially independent of speed. In general, there is no difference between the torque transmitted when a clutch is rotating and when it is not. This characteristic is a rather unique feature since, in all friction clutches, the breakaway torque is much greater than the slipping torque. In a magnetic-particle clutch, with the breakaway and running torques the same, there is a complete absence of chatter when the clutch is engaged.

In general torque will remain the same from standstill to full speed. Occasionally, there may be a design in which the magnetic particles align themselves more advantageously in the gap at higher speeds so that the torque will increase slightly as the speed increases. At very high speeds, a limitation due to the effect of centrifugal force on the magnetic particles is approached. The limitation is not fixed exactly since, up to a point, it can be partially overcome by greater coil current. However, if the speed goes high enough, no practical value of current or coil power is sufficient to hold the magnetic particles against the centrifugal force.

Expressing the speed limit in a simple exact figure is complicated by the particle action as this limit is approached. Once the magnetic particle chains are established, less current is necessary to hold them in place than was required to pull them in from the outer member. It also makes a difference which member is the driving member. In one case, the particles are all thrown as far as possible away from the inner member, and they must be pulled back against centrifugal force acrosss the intervening space. In the other case, the particles remain close to the inner member and are relatively easy to make into chains.

These effects have more bearing on a controlled slip clutch than on an "off-on" type. Thus, if the upper speed limit is to be approached, it is quite important to properly choose which shall be the driving member. However, for the normal clutch sizes and for speeds comparable to motor-drive speeds, this limitation is not usually a critical factor.

Fig. 5—Magnetic-particle clutch design in which slip rings have been eliminated

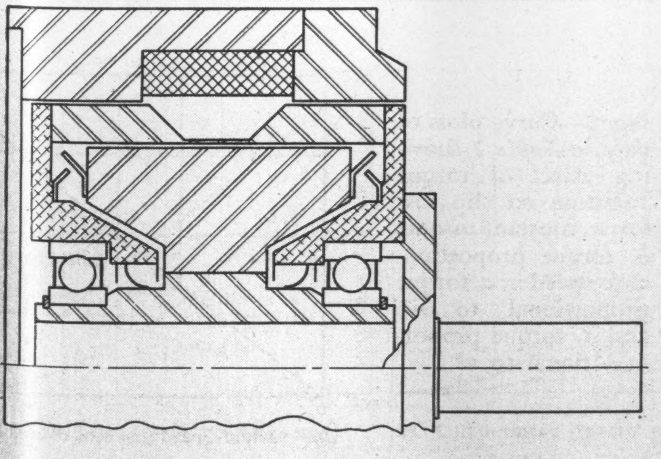
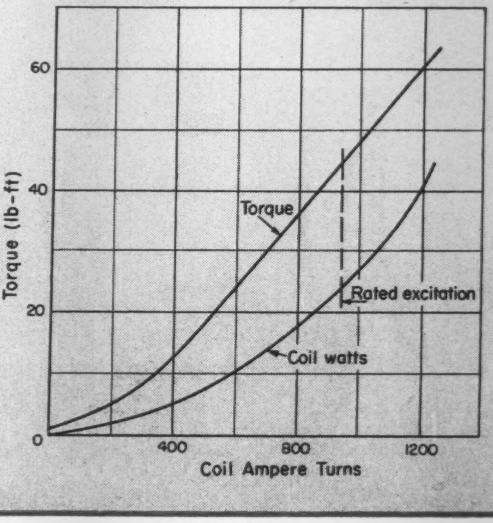


Fig. 6 — Typical performance curves for magnetic-particle clutch



Slip Loss: If it has been determined that the torque developed by the clutch will be sufficient for the application, the next factor to be considered is the heat which must be dissipated because of slip loss. This is a vital consideration.

The fact that the torque at each end of the clutch is the same must be kept clearly in mind. If the speeds at each end are different, the clutch is "slipping". The power at each end is proportional to the product of the corresponding values of torque and speed or, expressed in equation form,

$$P = \frac{Tn}{7050} \qquad (1)$$

where P = power in kilowatts, T = torque in pound-feet and n = speed in rpm. If the power into one end of the clutch is 10 kilowatts, and the power coming out the other end is 5 kilowatts, the difference of 5 kilowatts must be dissipated in the clutch as heat loss. For example, a power value of 10 hp, or 7.46 kw, corresponds to a torque of 30 lb-ft at 1752 rpm. Thus, if the input shaft is supplied with 30 lb-ft at 1752 rpm, 30 lb-ft will be delivered at the output shaft at any speed from 1752 to zero rpm. For the same speed at both ends, power input and output are equal and the slip is zero. No slip loss has to be dissipated by the clutch and the size of clutch is determined by torque requirements alone.

If on the other hand, the output torque of 30 lb-ft is delivered at half speed, 876 rpm, the power output, from Equation 1, will be: 30(876)/7050 = 3.73 kw. In this case, clutch slip, *s*, is 0.5 and the difference in power, or slip loss, is 3.73 kw. This slip loss must be dissipated as heat, and the heat-dissipating area of the clutch surfaces, rather than the torque capacity, will be the major factor in determining the size of the clutch. A clutch of a size adequate to dissipate the heat would provide torque sufficient to the application.

Should the output speed be zero, the amount of heat to be dissipated would be maximum and equal to the power input. There would be no actual power output, even though torque is exerted.

If it were not for the fanning effect created by the rotation of a part of the heat-dissipating surface, it would be more than twice as difficult to dissipate the heat. Clutches having large surfaces rotating at high speeds will, of course, dissipate more watts. Maximum air cooling can be attained by proper design of integral fans and fan blades. The heat-dissipating abilities of various sizes of typical clutches are given in *Table* 1.

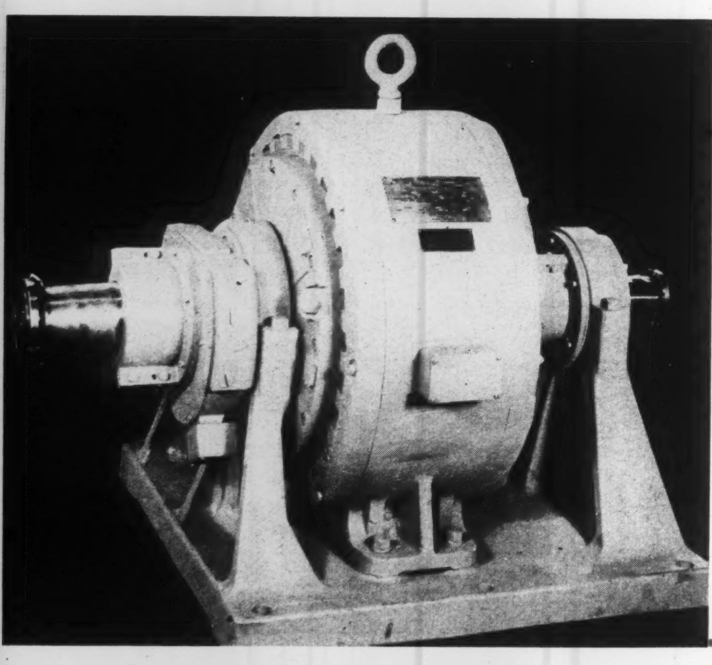
Water cooling is especially effective, particularly if both clutch members are cooled, but adds to clutch cost. A 300 hp water-cooled clutch which will dissipate over 70 kw heat loss has been developed, *Fig.* 7.

Table 1—Heat Dissipation of Typical Magnetic-Particle Clutches

Rated Torque (lb-ft)	Maximum Operating Speed (rpm)	Heat Dissipation* (watts)	Clutch Weight (lb)	Clutch Diameter (in.)	Clutch Length† (in.)
10	6000	100	29	6⅛	7¾
45	5000	315	74	8½	10½
100	4500	375	124	10	12
200	3600	430	233	12½	14¾

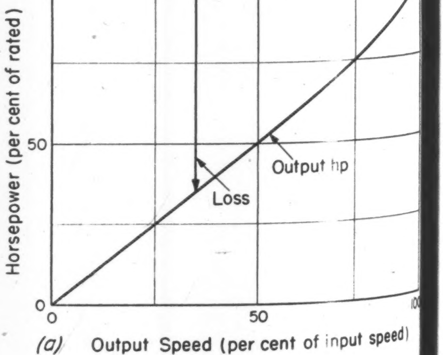
*At 1800 rpm of outer member. †Less shaft extensions.

Fig. 7—Water-cooled magnetic particle clutch for high slip applications. Rated at 300 hp, the design will dissipate 70 kw slip loss



Variable Torque Loads: In variable-speed applications, the torque may be constant regardless of speed, or may vary with speed. The manner in which torque varies has a great effect on the amount of slip loss and the speed at which the maximum loss occurs. The importance of this

Fig. 8—Curve plots of data in *Table* 2 showing effect of torque variation on slip loss for: *a,* constant torque; *b,* torque proportional to speed *n*; *c,* torque proportional to n^2; and *d,* torque proportional to n^3



effect on the maximum amount of heat which must be dissipated is illustrated in *Table* 2 and *Fig.* 8. For example, a much larger variable-speed clutch would be necessary for a friction load with constant torque from zero to full speed, *Fig. 8a,* than for a fan load where the maximum loss would be 14.8 per cent, occurring at two-thirds speed, *Fig. 8c.*

It is apparent that if speeds and loads are chosen to give the minimum amount of slip, the smallest clutch can be used. For example, it would be better to use a 14-pole, 3428-rpm generator, coupled to a 60 cycle, 3500 rpm drive motor, to produce 400 cycle current than a 16-pole, 3000-rpm generator. In the first case, the slip would be: $s = (3500\text{-}3428)/3500 = 0.0206$, or 2.06 per cent loss. In the second case, the slip would be: $s = (3500\text{-}3000)/3500 = 0.143$ or 14.3 per cent loss, almost seven times greater.

If it were necessary to use the 3000 rpm generator, it would be better, so far as the clutch is concerned, to use a drive motor with high slip. This would give less loss in the clutch, although the motor itself might be slightly larger and less efficient.

Acceleration: It has been mentioned previously that in "on-off" service, with the clutch "locked-up" and having no slip, there would be no loss. There is an exception to this rule, however, which should be considered for each application.

If the clutch is coupled to a high-inertia load, there will be slip loss during the accelerating period. The amount of energy which must be stored in the rotating load is

$$E = \frac{WR^2 n_L^2}{4330} \qquad \text{(2)}$$

where E = stored energy, watt-seconds; W = weight of rotating load, pounds; R = radius of gyration, feet; and n_L = load speed, rpm.

If the clutch goes from 100 per cent slip to zero slip, the average efficiency will be 50 per cent and the clutch must dissipate a loss exactly equal to the energy supplied to the load. As an example, assume that a clutch must start a steel flywheel 10 times a minute. The flywheel is 10 inches in diameter and 2 inches thick. Operating speed is $n_L = 1750$ rpm; sufficient braking torque is externally applied to bring the flywheel to rest between cycles. It is further assumed that there is no friction, and no inertia in the clutch itself or in any other unit except the flywheel. By calculation, $W = 44.3$ lb (weight of steel is taken as 0.282 lb/cubic in.) and $R = 0.295$ ft. From Equation 2, $E = [44.3(0.295)^2(1750)^2]/4330 = 2730$ watt-seconds.

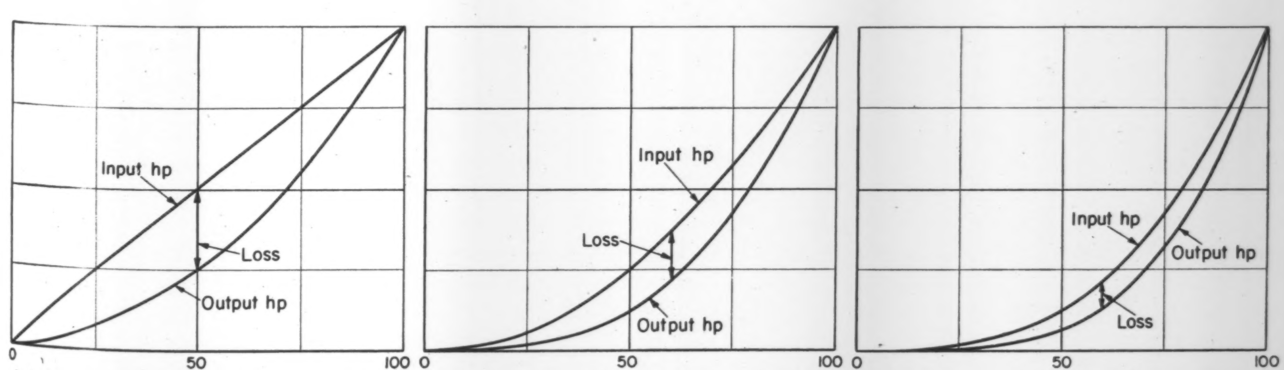
Since this energy must be dissipated each time the clutch starts the flywheel, the average power dissipation, based on 6-second operating intervals, is $2730/6 = 455$ watts.

If the problem is more complex, care must be

Table 2—Effect of Torque Variation on Slip Loss

Basic Relationships	Loss, L*	Max. Loss (per cent of input)	Max. Slip, s
T = constant $P \propto n$ (Friction Load)	$L = P_i s$	100	1.00
$T \propto n$ $P \propto n^2$ (Conveyor Load)	$L = P_i s\,(1 - s)$	25	0.500
$T \propto n^2$ $P \propto n^3$ (Fan Load)	$L = P_i s\,(1 - s)^2$	14.8	0.333
$T \propto n^3$ $P \propto n^4$	$L = P_i s\,(1 - s)^3$	10.53	0.250
$T \propto n^z$ $P \propto n^{z+1}$	$L = P_i s\,(1 - s)^z$	$\frac{z^z}{(z+1)^{z+1}}$	$\frac{1}{z+1}$

*Subscript notation i denotes input conditions.



(b) Output Speed (per cent of input speed) *(c)* Output Speed (per cent of input speed) *(d)* Output Speed (per cent of input speed)

exercised to evaluate all factors involved. For instance, *all* of the inertia to be accelerated must be accounted for, such as the inertia of the driven clutch member, couplings or pulleys and any reciprocating machine parts. The total WR^2 value for the system may be found by summing up the different individual WR^2 values, corrected to compensate for variations in motion characteristics. For machine parts rotating at speeds other than clutch speed, the corrected or effective value of WR^2 may be determined by applying a correction factor that is the inverse ratio of the square of the speeds. For example, the effective WR^2 value of a part rotating at a speed n_1, when translated to clutch shaft speed n_C, would be,

$$(WR^2)_{eff} = (WR^2)_1 \left(\frac{n_1}{n_C}\right)^2 \quad \ldots\ldots (3)$$

For parts moving in a straight line instead of rotating, the effective WR^2 value may be calculated from,

$$(WR^2)_{eff} = \frac{w\, v^2}{39.48\, n_C} \quad \ldots\ldots (4)$$

where w = weight of moving part, pounds, and v = linear velocity of moving part, fpm.

If, in addition to the inertia load, there is also a large friction or power load, the loss due to such load must also be added to the acceleration losses.

Braking: When a magnetic-particle clutch is used as a brake, all of the stored energy must be dissipated in the brake members. Since braking usually involves rapidly repeated stops, accurate calculation of losses is a fundamental step in determining brake size.

Clutch-Brake Applications: Clutch and brake combinations can be frequently used to advantage in production machinery to speed up operations. For these units, the torque necessary to start or stop a given amount of inertia in a given time can be calculated from,

$$T_s = \frac{WR^2\, n_L}{308\, t} \quad \ldots\ldots (5)$$

where t = time, seconds, and T_s = required starting or stopping torque, lb-ft.

Application Experience: After more than four years of continuous service, magnetic-particle clutches operating at from 2 to 10 per cent slip in military use and holding constant speed for laboratory generators still are operating with no signs of wear or other deterioration. Magnetic-particle brakes on tapping machines have operated as many as 2 million cycles with no sign of wear and without need of adjustment.

The ease with which magnetic-particle clutches and brakes can be applied in complicated automatic circuits, and for remote control, has stimulated their acceptance in these days of automation. Extremely low control power requirements permit use of minimum-sized electronic and magnetic amplifiers, which are necessary with low-level detectors such as thermocouples or photocells.

The excellent record of service established by the magnetic-particle clutch during the early years of development shows it be capable of a high degree of performance. Like any other device, however, it has its own particular sphere of use and should not be misapplied.

Monitor Watches Diesel Engine Operation

BECAUSE diesel engines operate most efficiently within a certain optimum temperature range, monitoring exhaust temperature can provide the operator with an indication of engine performance. As engine temperature rises, efficiency drops. Since load and efficiency of a diesel engine are directly related, exhaust temperature will rise as load increases.

Excessive exhaust temperature indicates an overloaded and inefficiently operating engine. To warn the diesel engine operator of an overload condition, Minneapolis-Honeywell Regulator Co. has developed an indicating device using a bimetal temperature element.

Two units comprise the complete device: an indicator and a sensing unit. Consisting of two pilot lights in a small case, the indicator may be mounted on a truck dash or on a motor control panel where it would be easily visible to the operator. The sensing device, or temperature-operated switch, is designed to be inserted into a tapped hole conveniently located in the exhaust system. Heart of the sensing unit is a helical bimetal switch which will open a normally closed contact at one temperature and close a normally opened contact at another temperature.

Power for the complete system can be provided by the vehicle storage battery. Any power source capable of lighting the pilot lamps is adequate.

In operation, an amber "caution" light indicates a lower than normal operating temperature. During operation at normal temperatures and normal efficiency, neither lamp is lighted. When exhaust temperature exceeds the predetermined danger point, a red indicator lights. In this way a truck driver can be warned to shift to a lower gear ratio to reduce the load.

Preliminary models, according to Minneapolis-Honeywell engineers, were set to indicate normal operation at temperatures between 450 and 650 F. However, adjustment is provided to alter this temperature range to fit any specific diesel engine or exhaust system.

By Paolo Tedeschi
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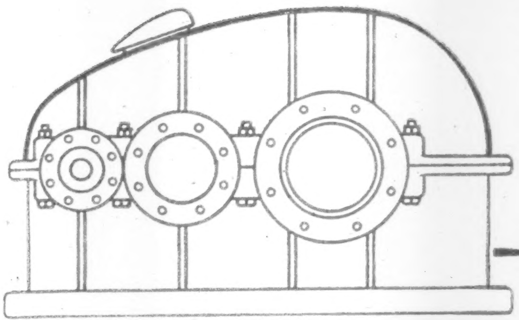
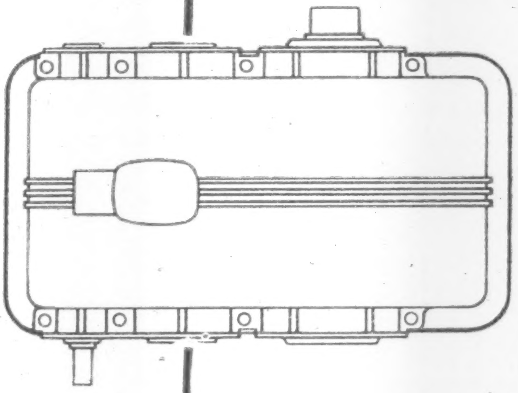


PLANNING MACHINE SERIES—5



In this, the concluding article of the series, attention will be given to several practical problems requiring special methods of attack for series planning. Representative types of machines to be treated include constant-speed pumps, reciprocating machines, centrifugal governors and servomotor speed regulators.

BASIC principles and methods of machine series planning treated in the two previous articles of this series are continued here with emphasis on several special design problems. In the following discussion, which is essentially an extension of *Part* 3, attention will be given to isotakic pump series—the common case of pumps directly driven by electric motors. Succeeding discussions consider several design problems involving special techniques of analysis. The solutions developed in these latter sections are presented, not so much for the significance of each particular case, but rather for the general observations and conclusions reached which may be useful in other problem areas.

Constant-Speed Pumps: For direct-driven pumps operating at fixed angular velocities, series planning is complicated by certain practical considerations which cannot be readily resolved by the fundamental criteria and methods demonstrated in *Part* 3. The nature of these difficulties is perhaps best illustrated by an analysis of the mixed-flow pump line developed in *Part* 3 and depicted graphically in *Fig.* 21.

For convenience, this chart has been duplicated in modified form in *Fig.* 28. Complete curve plots for each of the pump models in the line have been omitted and only the normal or design points, which lie among a line of constant head, $H = 37.9$ ft, have been shown. As an aid to analysis, dotted lines of $\omega_r = \omega/\omega_s =$ constant, are shown. These lines correspond to the specific speed of the pump line ($\omega_s = 5640$) and to the usual standard 60-cycle motor speeds (1740, 1160, 870 and 580 rpm). Also, through the normal point of each pump model, the corresponding line of specific volume is drawn.

It is evident that the points of intersection of these two families of dotted parallel lines represent, as shown, the normal points of the mixed-flow pump models operating under the fixed velocity conditions of the electric-motor drives. Thus, the mixed-flow pump line which was logical and rational as an isodromic series, has now become completely irrational, as if the models had been selected by chance. This result indicates that a homothetic line does not also lend itself to the function of an isotakic series or, that if the different requirements of both series have to be met, the criterion of selection must be revised.

Any attempt to distribute a homothetic series of several elements in the volume-pressure plane so as to make full use of the fixed velocities will only lead to failure because the velocity series has no relation to the progression that such a rational disposition would require. To overcome this difficulty, the velocities would have to follow a geometrical progression related to the progression of volume rates. Instead, they follow a reciprocal scale based on the numbers of poles of the electric motors.

The only way to realize rational results is through combination of various homothetic series, each of which may be composed of only a few terms. As a result of this procedure, the homothetic line losses the property of being a series derived from only one basic model. However, with this method it becomes possible to reach the fundamental objective of covering the proposed field of series application with a minimum number of models and with the most uniform, as well as economical, distribution. This planning technique requires special criteria which will be discussed in the following section.

Reticular Pump Series: The difficulties arising from the necessity of using the few fixed speeds of electric motors are at least partly resolved with the method of attack which shall be described. For clarity of understanding, it will perhaps be best if the problems related to particular cases are examined first and the solutions then extended to obtain general conclusions.

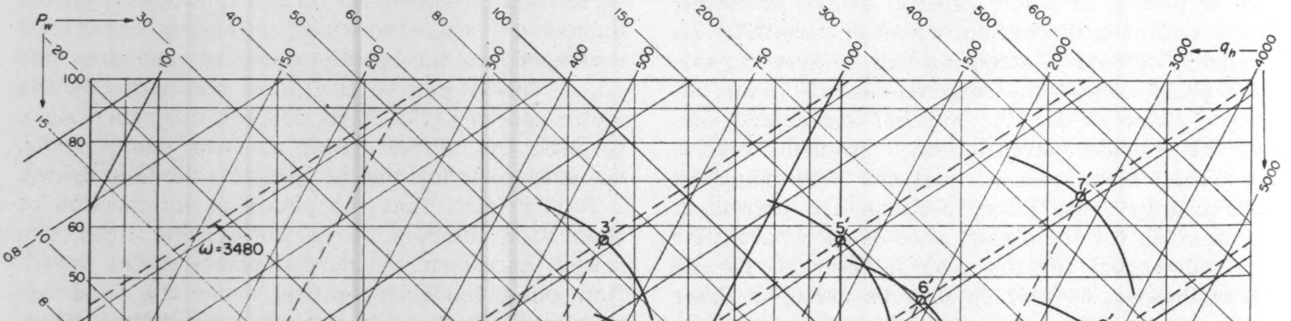
Assume a series of small and medium-size centrifugal pumps of the most common types, *Fig.* 29, is to be planned. These centrifugal pumps are to be directly coupled with electric motors operating at standard speeds of 3480 and 1740 rpm, thus giving a ratio between speeds of 2. Maximum head to be generated is assumed to be $H = 160$ ft; minimum pressure is a function of the lower of the two speeds. Minimum specific volume is $q_h = 4.7$.

The limiting values given for maximum pressure and minimum specific volume determine the normal operating point of the smallest pump of the series. On the magnified section of a *q-H* logarithmic chart, *Fig.* 30, this point is designated as A_1 and has a corresponding normal volume rate of $q_1 = 60$ gpm. This pump which, like all the other units of the series, must operate at 3480 and 1740 rpm is actually represented on the chart by two points, A_1 and A_1', located on the line of constant specific volume, $q_h = 4.74$. The point A_1' will have an ordinate of $H_2 = 40$ ft, which is found by dividing the ordinate value corresponding to A_1 ($H_1 = 160$ ft) by the square of the velocity ratio, $H_2 = 160/2^2 = 40$ ft. Thus, it is apparent that homologous plots for all pumps of the group having a normal head of $H_1 = 160$ ft will fall along the constant ordinate line of $H_2 = 40$ ft.

On the chart of *Fig.* 30 let a straight line corresponding to $\omega_r =$ constant be drawn through A_1'

Correction: In *Fig.* 15 of this series (September issue) P_w represents output power, hp, instead of input.

Fig. 28—Curve plots of homothetic series of mixed-flow pumps with normal points shifted for operation at standard electric-motor speeds. Modified points are designated by prime notation; normal points of basic pump models correspond to the mixed-flow pump series shown in *Fig.* 21 of *Part* 3



and extended to intercept the constant ordinate line, $H_1 = 160$ ft, at D_1 as shown. Before discussing the significance of this point further, it will perhaps be helpful to see if there is a relation, and in the affirmative case just what the nature of the relationship is, between the volume rates of the points A_1 and D_1.

It can be readily demonstrated by both analytical and graphical techniques that if ω_1 and ω_2 are the operating pump speeds for points A_1 and A_1', respectively (3480 and 1740 rpm in this case), the ratio between the volume rates for A_1 and D_1 is equal to the square of the reciprocal ratio between the two speeds, $(\omega_1/\omega_2)^2$. In effect, using the symbols defined in *Fig.* 30 and applying similarity laws to the pump A_1-A_1', the following expressions are found:

$$\frac{q_3}{q_1} = \frac{\omega_2}{\omega_1} \qquad (63)$$

$$\frac{H_2}{H_1} = \left(\frac{\omega_2}{\omega_1}\right)^2 \qquad (64)$$

For the case of similarity between homothetic and isotakic machines as represented by points A_1' and D_1, referring to Formulas 40 and 41 of *Part* 3,

$$\frac{q_2}{q_3} = \left(\frac{H_1}{H_2}\right)^{3/2} \qquad (65)$$

From Equations 64 and 65,

$$\frac{q_2}{q_3} = \left(\frac{\omega_1}{\omega_2}\right)^3$$

and combining this equation with Equation 63 gives the result sought:

$$\frac{q_2}{q_1} = \frac{q_2}{q_3}\left(\frac{q_3}{q_1}\right) = \left(\frac{\omega_1}{\omega_2}\right)^3 \frac{\omega_2}{\omega_1} = \left(\frac{\omega_1}{\omega_2}\right)^2 \qquad (66)$$

Graphical proof of this relationship, based on the logarithmic q-H chart, is equally simple. It is only necessary to prove that the base A_1D_1 of the triangle $A_1D_1A_1'$ is equal in length to its altitude, $H_1 - H_2$. If this condition is fulfilled, Equation 66 is then a valid relationship since

$$\log q_2 - \log q_1 = \log H_1 - \log H_2$$

From this equation, converting to the corresponding antilog form and referring to Equation 64, Equation 66 can be directly derived.

In *Fig.* 30, let Z be the point where a vertical line drawn through A_1' intercepts the horizontal ordinate line common to A_1 and D_1. From the chart construction, the relationships between line lengths are then:

$$ZA_1 = \frac{ZA_1'}{2}$$

$$ZD_1 = \frac{3ZA_1'}{2}$$

and, finally,

$$A_1D_1 = ZD_1 - ZA_1 = ZA_1'$$

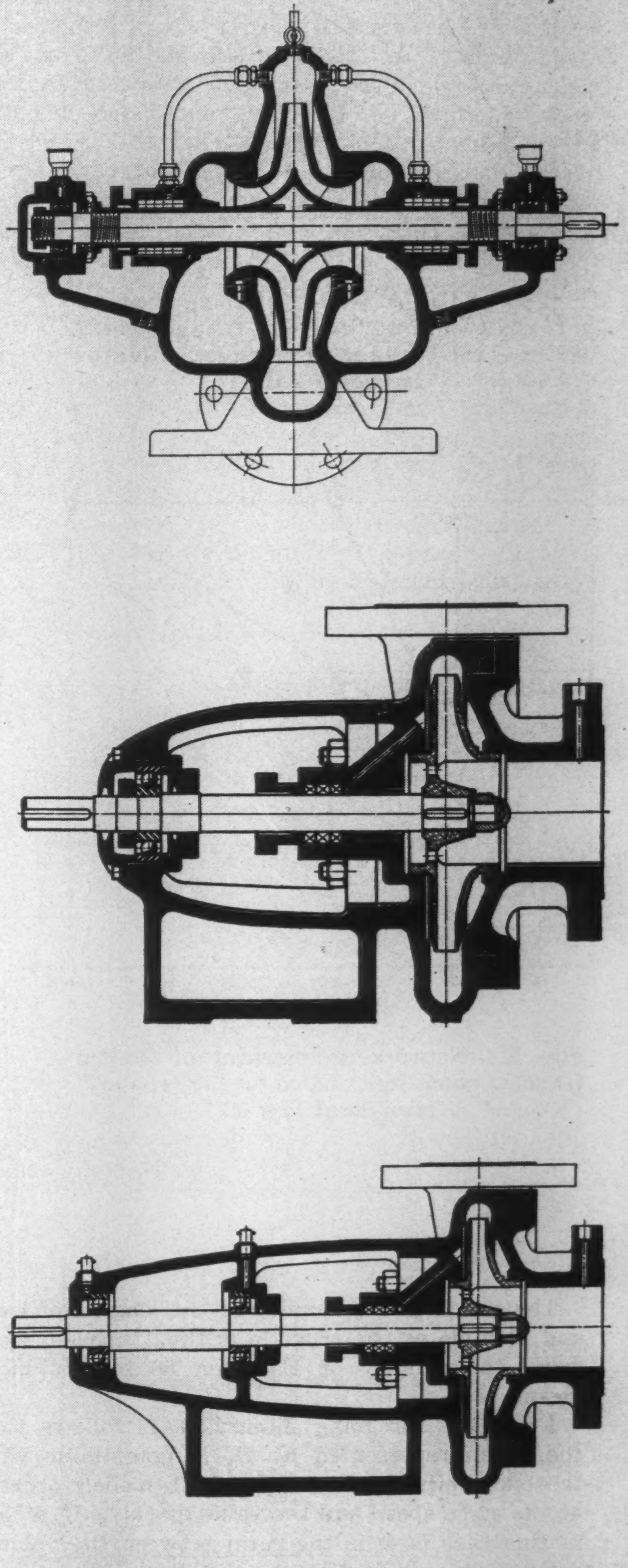


Fig. 29—Typical electric-motor driven centrifugal pump designs showing medium-size double-inlet unit and two small-size units for normal operation at high and low speed

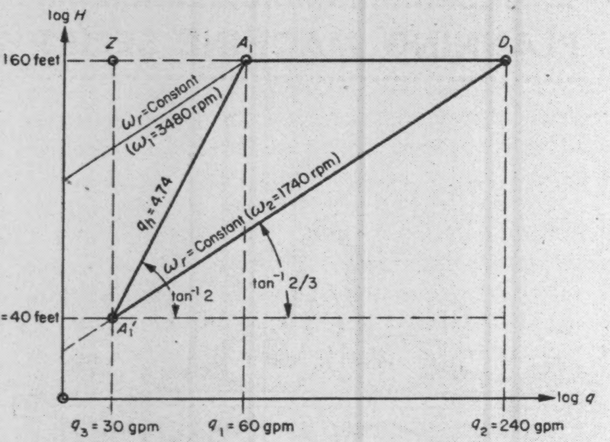


Fig. 30—Enlarged section of comprehensive *q-H* chart showing "*H*-ω_r-q_h" triangle which serves as the basis for development of reticular pump series

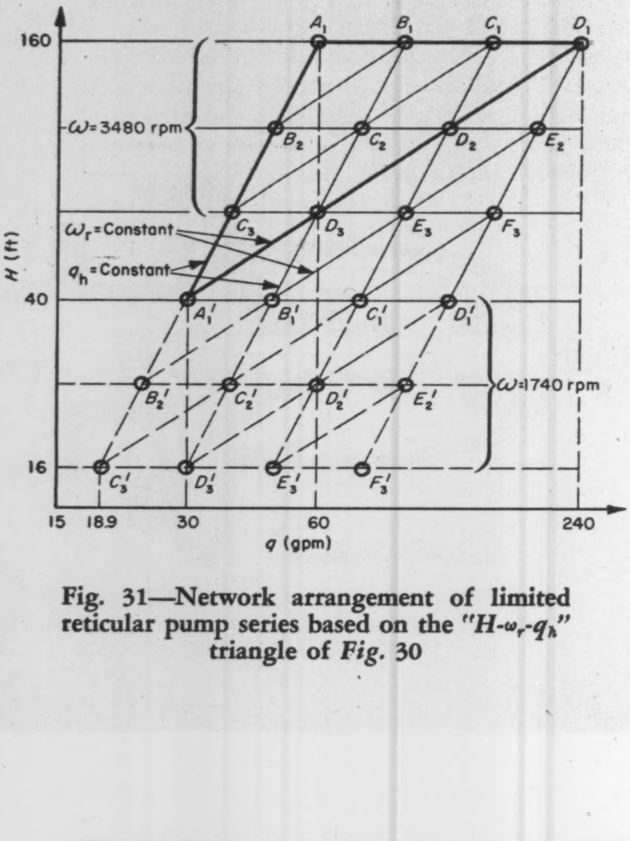


Fig. 31—Network arrangement of limited reticular pump series based on the "*H*-ω_r-q_h" triangle of *Fig.* 30

The condition of equality of the lengths of base and altitude of the triangle is thus fulfilled, verifying the validity of Equation 66 by graphical means.

From the foregoing discussion, it follows that the pump represented by D_1 is homothetic with the one represented by A_1' if both models operate at the same speed and the value of $(\omega_1/\omega_2)^2$, which in this case is 4, is the ratio between the volume rates corresponding to A_1 and D_1. However, as pointed out in the previous discussions of selection criteria for ratios of a series, the use of high ratio values, such as $r=4$, is not practical and should be avoided. For the case under analysis, this limitation means that a certain number of pump models will have to be determined by interpolation between A_1 and D_1. These interpolated models will operate under 3480 rpm with characteristics corresponding to the point plots along the line A_1D_1 and under 1740 rpm in accordance with homologous point plots on the constant ordinate line passing through A_1'.

If, for example, the segment A_1D_1 is divided into three equal parts by points B_1 and C_1 as shown in *Fig.* 31, the ratio between the volume rates of two adjacent or successive points is $\sqrt[3]{4} = 1.5874$. This value closely approaches the term ratio of the ASA standard 5-series of preferred numbers.

In *Fig.* 31 lines of ω_r = constant and q_h = constant have been drawn through the interpolated points, B_1 and C_1. For the families of parallel lines thus obtained, it can be readily shown that a network of parallelograms is produced in which each group of intercepts lies along a line of constant pressure. In addition, these points represent pump models which are homothetic with the corresponding models of points A_1, B_1, C_1 and D_1.

The lines of ω_r = constant, when extended to the segment $A_1'D_1'$, determine the homologous point plots for homothetic units according to the condition, q_h = constant. As a result, the groupings contained within the parallelogram $A_1D_1D_1'A_1'$ may be duplicated below the constant ordinate line $A_1'D_1'$, extending the network of parallelograms to the base line $C_3'F_3'$. This base line is located on the constant ordinate line, $H = 16$ ft, as shown in *Fig.* 31.

In this expanded network diagram, it will be noted that pumps comprising homothetic series have been identified by the same letter designation; equivalent numerical subscripts are carried by the models of equal specific volume in each group. Because of the characteristic network form of arrangement, this special group of machines is perhaps most aptly described as a "reticular" group or line.

As indicated previously, the horizontal distances between subsequent point plots in *Fig.* 31 represent the ratios of the progression of volume rates. In addition, the vertical distances between successive horizontal lines in the network grouping are a measure of the ratios between corresponding heads. From the network construction, based on similitude of triangles and the foregoing discussion, it can readily be shown that the volume rate ratio is equal to the pressure ratio.

A more detailed graphical analysis of the application range of several pump models has been developed in *Fig.* 32. The characteristic pump curves which pass through the normal points are limited in each case by the largest permissible volume rates corresponding to the minimum allowable efficiency value. These limiting points appear in *Fig.* 32 as points *M* and *N*.

In *Fig.* 32, it will be noted that a gap exists between the head values corresponding to the points *N* of the upper range of pumps and those corresponding to the points *M* of the lower range of pumps. The zone of head values lying between the constant ordinate lines which pass through these points represents an undesirable discontinuity. To alleviate this condition, a certain number of impellers of reduced diameter may be planned, permitting the application range to be extended to smaller heads than those possible with the normal impellers.

The shape of the characteristic curve of a pump with an impeller of reduced diameter is similar to that obtained with an impeller of normal size. On the logarithmic q-H chart, *Fig.* 32, the effect of diameter reduction appears as a displacement of the normal characteristic curve, downward and in the left-hand direction at an angle of 45 degrees. In this displacement process, the curves corresponding to different impeller sizes remain parallel.

To extend the range of pump B_1 in *Fig.* 32, three impellers of reduced diameter have been planned. Characteristic curves for these impellers are defined by points B_{11}, B_{12} and B_{13}. For this extended range, it is evident that any constant ordinate line between the points M and N of the upper and lower pump groups, respectively, will now intersect at least one or more normal or reduced diameter characteristic curves. The gap previously mentioned has been eliminated and for any given head value there will always be a corresponding volume rate. Operating points, in each case, will always be within the limits imposed by the minimum allowable efficiency value.

Another method of employing impeller reduction to fill out application ranges is demonstrated in *Fig.* 33. In this case, the ratio of volume rates for pumps A_1 and B_1 was considered to be too great. To achieve a more gradual increase in volume rates, a model with an impeller of reduced width has been inserted between A_1 and B_1. In *Fig.* 33, this model appears as point R_1 which is located midway between A_1 and B_1. The ratio of volume rates achieved with the inserted model is thus equal to the square root of the ratio between pumps A_1 and B_1.

The discontinuity of head values between upper points N and lower points M has been filled in, *Fig.* 33, by means of two models with impellers of reduced diameter. One impeller, B_{12}, has been derived from pump B_1 and the other, R_{11}, has been derived from pump R_1 which already has an impeller of reduced width. This latter impeller, R_{11}, may be derived from pump B_1 by a simultaneous reduction in impeller width and diameter.

The three derived pump units with modified impellers will have characteristic curves similar to those of the basic models. On the logarithmic q-H chart, *Fig.* 33, the effects of the two methods of impeller modification appear as parallel displacements of the characteristic curve of the basic model, shifting in a horizontal direction for impeller width reduction and downward at an angle of 45 degrees for impeller diameter reduction. Thus, in *Fig.* 33, the previously empty pressure zone is now filled by an isobaric series of pumps derived through impeller reduction, alternately, of (1) the diameter alone, B_{12}, and (2) both the width and diameter, R_{11}.

If, for a first approach, it is assumed that there is an exact affinity between the different characteristic curves, it follows that the curve images on the logarithmic chart will be identical. Thus, the progression of volume rates determined by the intersection of a line of constant head with the characteristic curves of the derived isobaric pump series is also duplicated on any other intersecting, constant ordinate line.

In actual practice, the similarity between the shapes of the characteristic curves for basic and modified impellers is not exact. However, the small differences in the progression of volumes resulting from this lack of identical curve duplication are perfectly tolerable. As a result, the pump series just described is perhaps one of the most rational that can be developed.

In reference to the reticular arrangement in *Fig.* 31, it will be noted that the series depicted has been limited to a single group. The same

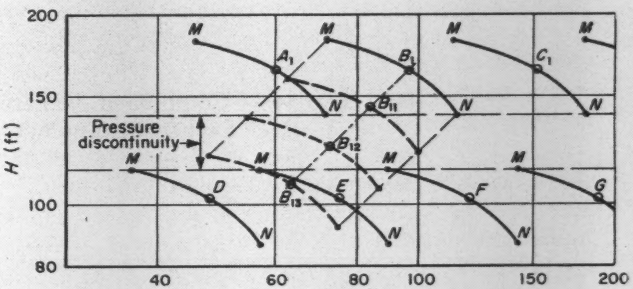


Fig. 32 — Graphical analysis of reticular pump series showing method of filling-in series discontinuities with impellers of reduced diameter

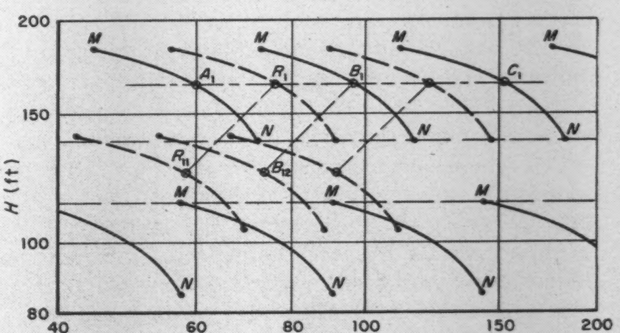


Fig. 33 — Graphical analysis of reticular pump series showing alternative method, as compared to *Fig.* 32, of filling-in series discontinuities with impellers of reduced diameter and width

Table 14—Basic Planning Date for Reticular Pump Series

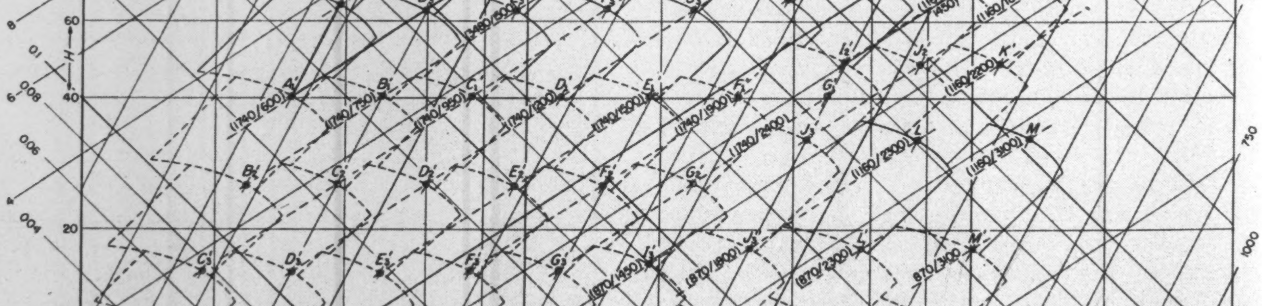
Motor Speed Ratio	2						1.5				1.333		
Motor Speeds, rpm	3480/1740; 1740/870; 1160/580						1740/1160				1160/870		
Volume Rate Ratio*	4						2.25				1.778		
Number of Terms	3	4	5	6	7	8	3	4	5	6	3	4	5
Progression Ratio	2.00	1.587	1.414	1.320	1.260	1.219	1.500	1.310	1.224	1.176	1.333	1.211	1.155
Series Term Values†:													
Term No. 1	1.00‡	1.00‡	1.00‡	1.00	1.00‡	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	2.00	1.60	1.40	1.32	1.25	1.22	1.50	1.31	1.22	1.18	1.33	1.21	1.16
3	4.00	2.50	2.00	1.75	1.60	1.49	2.25	1.72	1.50	1.38	1.78	1.47	1.34
4		4.00	2.80	2.31	2.00	1.81		2.25	1.83	1.62		1.78	1.55
5			4.00	3.05	2.50	2.20			2.25	1.91			1.78
6				4.00	3.15	2.68				2.25			
7					4.00	3.27							
8						4.00							

* Equal to ratio of heads. † Values of extreme and intermediate terms correspond to first term reference value of 1. ‡ These series closely approximate some of the standard preferred-number series; terms have been accordingly assigned standard rounded-off numerical values.

arrangement could be repeated in the right-hand direction and extended as far as the maximum value of specific speed for the particular pump type permits. In the case under discussion, for example, the specific speed of the pump D_1 when operated under a speed of $\omega = 3480$ rpm is $\omega_s = 1200$. If this group were identically repeated in the right-hand direction, a point would be eventually reached where the operating conditions are: $q = 1500$ gpm, $H = 160$ ft, $\omega = 3480$ rpm and $\omega_s = 3000$. This specific speed value is near the limiting value for pure centrifugal pumps.

On the basis of criteria previously discussed, it may be convenient to increase the number of subdivisions in the range of volume rates of this second group. The objective of this smaller break-

Fig. 34 — Comprehensive network arrangement for complete reticular line of centrifugal pumps. Plots are based on data in *Table* 15



down is to reduce the ratio between subsequent volume rates. If a comparison is made of the original and repeated pump network groups, it will be found that the power input in the first case will be approximately in the range of 3 to 10 hp, while in the second group inputs up to 60 hp are reached. Since it is desirable, as a basis for the design of the pump network, to have smaller efficiency losses with increased power ratings, it will be necessary that the ratio of volume rates diminishes as the region of larger volume rates is approached.

As previously pointed out, the vertical distance between successive horizontal lines in the pump network, *Fig.* 31, is equal to the length of the horizontal line segment which represents the ratio between subsequent volume rates. Since the use of impeller reduction, in lieu of new models, to fill gaps in pump series cannot be practiced without some loss in efficiency, it is advisable to decrease this vertical interval when approaching the region of larger volume rates. The need for this procedure is influenced by the fact that as the volume rate becomes larger the economical importance of each pump unit increases. In addition, if the range of volume rates is subdivided, as discussed previously, to reduce the volume rate ratios, the vertical interval must automatically diminish to maintain the required equality between horizontal line segments and vertical distances in the network arrangement.

Table 15—Development of Combined Reticular Pump Series*

Specific Speed, ω_s	Motor Speed, ω (rpm)	——Point Plots (*Fig.* 34)——					
600	3480	A_1					
600	1740	A_1'					
750	3480	B_1	B_2				
750	1740	B_1'	B_2'				
950	3480	C_1	C_2	C_3			
950	1740	C_1'	C_2'	C_3'			
1200	3480	D_1	D_2	D_3			
1200	1740	D_1'	D_2'	D_3'			
1450-1500	3480	E_1	E_2	E_3			
1450-1500	1740	E_1'	E_2'	E_3'	I_1	I_2	I_3
1450-1500	1160				I_1'	I_2'	
1450-1500	870						I_3'
1800-1900	3480	F_1	F_2	F_3			
1800-1900	1740	F_1'	F_2'	F_3'	J_1	J_2	J_3
1800-1900	1160				J_1'	J_2'	J_3'
1800-1900	870						J_3''
2200-2400	3480	G_1	G_2	G_3			
2200-2400	1740	G_1'	G_2'	G_3'	K		
2200-2400	1160				K'	L	
2200-2400	870					L'	
3100	1160	M					
3100	870	M'					

*Summary of quantities: Number of different specific speeds (homothetic lines), 8; number of models to be developed, 27; number of operating points derived from reduced speed operation of basic models, 28; total number of operating points, 55.

For the series planning example which served as the basis for this pump network development, a ratio of 2 between operating speeds of models within the same group was established and the ratio between extreme volume rates was given as 4, *Fig.* 30. The ratio between volume rates has, in turn, been subdivided into three parts by inserting two intermediate models, *Fig.* 31. As a result of this subdivision, the ratio between subsequent volume rates was reduced to a value of 1.58.

This example, however, is only illustrative and should not be taken as the general case. In actual practice, a variety of different conditions may occur with regard to the ratio between fixed speeds of electric motors as well as to the ease of establishing subdivisions of the volume rate range according to a certain pattern. For instance, if the pumps in the left-hand chart region of the group were smaller than those of the present example, it might be advisable to divide the range of volume rates into two regions rather than three. Only one intermediate model would have to be determined by interpolation, giving a ratio between volume rates of 2.

A useful reference for the analysis of permissible volume rate ratios is *Table* 10 of *Part* 3. This table indicates that a ratio of 2 is suitable for small centrifugal pumps while for the intermediate pump sizes it is evident that a value near 1.54 is more advisable.

For purposes of rapid calculation, pertinent data related to the different series planning problems encountered in practice have been collected in *Table* 14. Included in this table are the relationships for different electric motor speed combinations as well as series planning data for varying numbers of interpolated models on the upper side of the basic triangular grouping which is shown in the magnified view in *Fig.* 30.

In the development of reticular pump lines, as demonstrated in the preceding discussion, the intention has been one of attaining, simultaneously and harmoniously, homologous speed groupings, homothetic relationships between similar pumps, constant pressure operating conditions and reduction of the volume rate ratio with increasing size and power and, hence, economic importance. The fundamental rationality of the resulting line is indicated, both directly and intuitively, by the uniform distribution of the network arrangement on the logarithmic *q-H* chart.

Combined Reticular Pump Lines: An example of how several reticular pump series may be combined to provide uniform coverage of an extensive application field is furnished by *Fig.* 34. In this comprehensive network, the following groups may readily be recognized:

1. A reticular group with base A_1 D_1. In this group the ratio between electric motor operating speeds is 2 and, accordingly, the ratio of volume rates is 4. The volume rate range has been subdivided into three equal regions by inserting two intermediate models B_1 and C_1. In terms of fundamental models, this reticular group encompasses the field defined by the parallelogram $A_1D_1F_3C_3$. However, if the derived models operating at minimum speed are included, this field is extended to the line $C_3'F_3'$.
2. A reticular group obtained by repeating the network of group 1 in the right-hand direction. This group reaches to the constant q_h line which joins F_1 and I_3'.
3. A reticular group with base G_1J_1. In this group the ratio between electric motor operating speeds is 1.5 and, thus, the ratio between volume rates is 2.25. The volume rate range has been subdivided into two equal parts by inserting an intermediate model I_1. For this group, homologous models operating at low speed extend the network to the isobaric line $I_2'J_2'$.
4. A simple reticular group with base *LM*. Models *L* and *M* operate at 1160 rpm and their homologous counterparts, *L′* and *M′*, at 870 rpm.

The elements making up this combined network are summarized in *Table* 15 which notes the number of groups of pumps with the same characteristics, the different pump models to be designed and the total number of points making up the field network.

It should be remembered that homologous point plots corresponding to models operating at reduced speed do not always represent pumps having a construction identical to those of the basic models. As a result of the lower velocity and power input characteristics of these units, design of the mechanical construction may be influenced by a number of considerations which offer reduced cost. Factors to be considered include number and type of bearings, shaft diameters, impeller guides, etc.

Reciprocating Machines: In the case of engines, fluid motors and operators (pumps and compressors) or other similar types of machines which employ single or multiple reciprocating pistons for power conversion, rational series planning requires a method of attack somewhat different from those previously discussed.

Appropriate geometrical modules for these machines include the total displacement of the cylinders or, for homothetic series, the cylinder diameter. The operational module will vary for each specific machine type and will be represented by different properties such as power output for engines, inlet flow rate for compressors and pumps, etc.

When the dynamic operating conditions of the particular machine type have been clearly established, the operational module takes on a proportional relationship with the total piston displacement. Series analysis may thus be based initially on either the operational modules or the piston displacements and later extended to include the geometrical properties of diameter and stroke. However, for this method of planning the fundamental kinematic conditions of operation must be pre-established. It must be known whether the series will be (1) of the isotakic type with crankshaft rotational speed remaining constant or (2) isodromic with a constant mean piston speed, or, (3) one in which both rotational and piston speeds vary according to a definite law.

For this analysis, symbols are defined as follows:

c = Number of cylinders
D = Cylinder diameter, inches
e = Number of piston actions
l = Piston stroke, inches
N = Crankshaft rotational speed, rpm
Q = Actual flow rate, gpm
Q_g = Geometrical flow rate or total cylinder displacement, gpm
$R = l/D$ = Stroke-diameter ratio
U = Mean piston speed, fpm
V_p = Piston displacement (unit), cubic inches
η_v = Volumetric efficiency

For a single-cylinder, single-acting machine:

$$Q = \eta_v Q_g = \eta_v \frac{V_pN}{231} = 0.0034\ \eta_v D^2 l N \qquad (67)$$

and, since $N = 6U/l$,

$$Q = 0.0204\ \eta_v D^2 U \qquad (68)$$

For the general case of any number of cylinders and single or double-acting pistons ($e = 1$ or 2, respectively), from Equation 67,

$$N = \frac{Q}{0.0034\ c\ e\ \eta_v D^2 l} \qquad (69)$$

Also, from Equation 68,

$$Q = 0.0204\ c\ e\ \eta_v D^2 U \qquad (70)$$

and solving for D,

$$D = \sqrt{\frac{Q}{0.0204\ c\ e\ \eta_v U}} \qquad (71)$$

In the usual type of series arrangement, where the numbers of cylinders and piston actions are constant, the conditions offering the most logical basis for planning are the homology of analogous geometrical dimensions and the uniformity of piston speeds (c, e, R, and U are constant). Under these conditions, from Equations 70 and 71, $Q = KD^2$ or $D = \sqrt{Q/K}$ where $K = 0.0204\ c\ e\ \eta_v U$.

In the progression of flow rates, let Q_1 be the first term, r_{Q1} be the first term ratio and ρ_Q be the second order ratio. Then, based on the properties of second order progressions, corresponding quantities for the progression of diameters are

$D_1 = \sqrt{Q_1/K}$, $r_{D1} = \sqrt{r_{Q1}}$ and $\rho_D = \sqrt{\rho_Q}$.

Assume, for example that a series of triplex single-acting pumps with the following characteristics is to be planned: Stroke-diameter ratio, $R = 1.5$; minimum and maximum flow rates, 10 and 100 gpm; constant piston speed, $U = 70$ fpm; and volumetric efficiency, $\eta_v = 0.70$. Also, for a first approach, it will be assumed that the volumetric efficiency is the same for all models. The coefficient K is, in this case: $K = 0.0204\,(3)(1)(0.70)(70) = 3$.

From *Table* 5 of *Part* 2, planned progression 10-5-B will be taken as the one that best meets the series requirements. This planned progression has 5 terms, first term ratio of 2.239, a last term ratio of 1.413 and a second-order ratio of 0.858. For the progression of diameters, $D_1 = \sqrt{10/3} = 1.83$ inches, $r_{D1} = \sqrt{2.239} = 1.496$, $r_{D4} = \sqrt{1.413} = 1.189$ and $\rho_D = \sqrt{0.858} = 0.926$.

From these data and the formulas given in *Part* 2 for development of second-order progressions, the three series of volumes, diameters and strokes can be determined as shown by the light-face values in *Table* 16. The series of strokes can be calculated directly from the relationship, $l = R\,D$, using the given value of $R = 1.5$ which has been taken as the characteristic homology factor of the series.

The initial values of diameters and strokes which have been calculated to the nearest 1/100 of an inch, must be rounded off to convenient or standard dimensions. Crankshaft speeds, N, which vary uniformly along the series because of the constant value of U, may then be calculated from Equation 69, using these final, and actual, values of diameters and strokes.

Corrected values of volumetric efficiency may be taken into account in the final calculation. The value of η_v, instead of remaining constant as was initially assumed, will actually vary along the series, increasing gradually from the small to the large models. Results of the final calculation for this example are bold-face in *Table* 16.

In rounding off diameter and stroke dimensions, standard sizes should be adopted, if possible. However, if this practice threatens the rationality of the series of operational modules, it would probably be more convenient to specify a nonstandard size which is closer to the calculated dimension. Elimination of one or two special gages, for example, may be poor compensation for the irrationality resulting from too large a difference between theoretical and rounded-off values.

Because of the small number of terms, the second-order progression in this example can not be replaced by series of preferred numbers. Such a procedure would eliminate the fundamental characteristic of the series—the progressive decrease in the values of the term ratios.

In the field of internal combustion engines, as well as other areas, series of multicylinder machines must often be developed in which the individual models have varying numbers of equal-size cylinders. Since output is exactly proportional to total displacement, the series of geometrical modules (displacements), as well as the series of operational modules (outputs), must be based on arithmetic progressions. For these progressions, successive term values will differ by a constant amount equal to either the power output or displacement of a single cylinder, depending on the series. In this case, the type of progression to be chosen is readily apparent. It is only necessary to remember the important properties of these progressions. Particularly, in the 1 to 12 cylinder range, which is the most used, the ratio between successive terms diminishes from an initial value of 2 to 1.0909, (*Table* 7, *Part* 2). If the first engine of the series has 2 or 3 cylinders, instead of 1, the initial term ratio drops to 1.5 for the two-cylinder design or 1.333 for the three-cylinder type, thus approaching more closely the usual values which are employed.

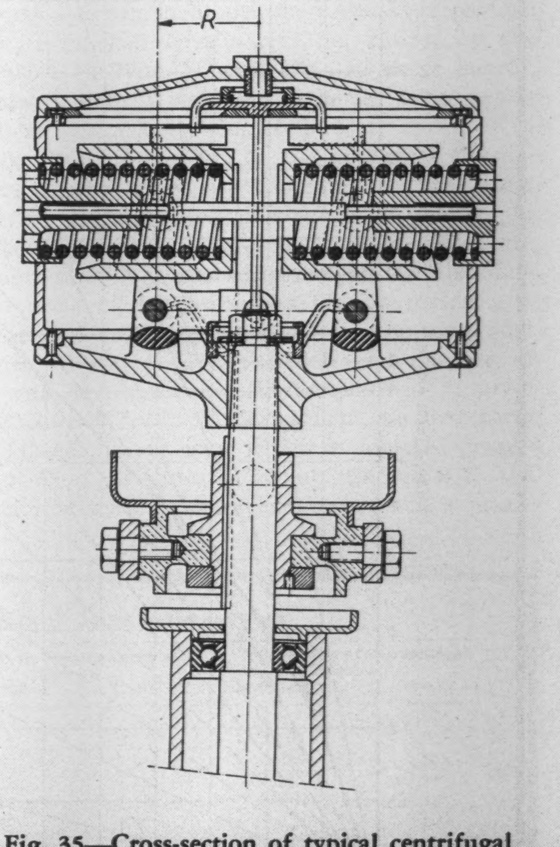


Fig. 35—Cross-section of typical centrifugal governor design which is used on hydraulic and thermal engines

Table 16—Calculated Data for Triplex Pump Series*

Term No.	Volume Rate, Q (gpm)	Volume Rate Ratio	Cylinder Diameter, D (in.)		Piston Stroke, l (in.)		Volumetric Efficiency, η_v (per cent)		Crankshaft Speed, N (rpm)
1	10	. . .	1.83	**1⅞**	2.74	**2¾**	70	**65**	**156**
2	22.4	2.24	2.73	**2¾**	4.10	**4⅛**	70	**67.5**	**105**
3	43	1.92	3.78	**3¾**	5.67	**5 11/16**	70	**70**	**75**
4	70.8	1.65	4.86	**4⅞**	7.29	**7¼**	70	**72.5**	**56**
5	100	1.41	5.77	**5¾**	8.66	**8 11/16**	70	**75**	**46**

*Initial calculations are designated by light-face type; final calculations by bold face type.

Centrifugal Speed Governors: Among the many types of speed controllers for hydraulic and thermal engines, the design shown in *Fig.* 35 is typical of one that is still commonly adopted (at least in Europe) where high quality control is not needed.

The dynamic component of the regulating action of these speed governors is the centrifugal force of the revolving weights. This force is transmitted by levers to the sliding sleeve where it becomes an axial force, which varies in magnitude at different positions of the sleeve stroke. Its value at the middle point of stroke is called, by the improper but nevertheless commonly used term, "mean energy of the governor."

In the following discussion, a well-established line of such controllers, in common use for about 30 years, will be analyzed. This series constitutes an interesting early approach to rational series planning.

The linkage design of these governors is such

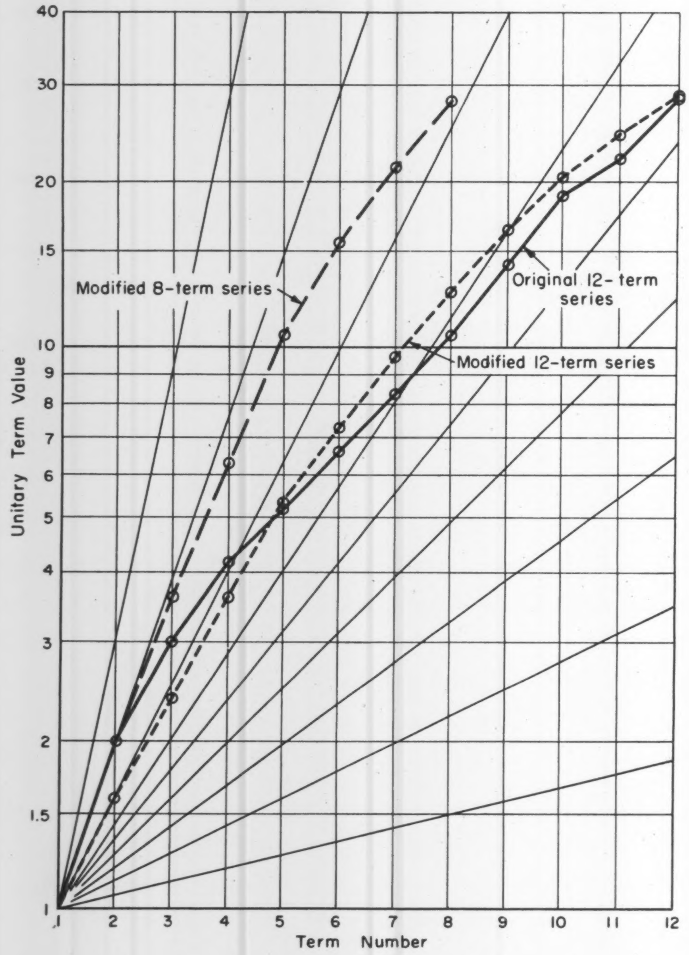


Fig. 36 — Graphical analysis of line of centrifugal governors showing curve plots of original 12-term series of operational modules and two improved series groupings, of 12 and 8 terms, derived from second-order progressions

that the centrifugal forces of the rotating masses are transmitted without mechanical advantage, at a "transmission" ratio of 1/1, to the sliding sleeve.

Symbols are as follows:

E = Mean energy of governor, as defined previously, pounds
g = Acceleration of gravity (32.16 ft per second per second)
N = Angular speed, rpm
R = Radius of rotation of the center of gravity of the revolving weights in the half-stroke position, inches
U = Lineal speed of the center of gravity of the masses, fps
W = Weight of each rotating mass, pounds
ω = Angular speed, radians per second

The fundamental relationships for this governor design are:

$$E = 2\frac{W}{g}\omega^2 R$$

$$E = 2\frac{W}{g}\frac{U^2}{R}$$

Inserting appropriate units gives,

$$E = \frac{WN^2R}{17{,}600} \qquad (72)$$

$$E = \frac{WU^2}{1.34\,R} \qquad (73)$$

A series of centrifugal governors could be readily developed on the basis of several different criteria, as in the case of pumps. However, the most interesting grouping is one, analogous to the homothetic-isodromic centrifugal pump series (*Part* 3), based on geometrical similarity of homologous linear dimensions and constant linear velocity of the center of gravity of the rotating masses.

As geometrical module of these units, any one of the principal linear dimensions may be adopted, for example, the radius R. The operational module will be the energy quantity, E. Based on the geometrical similarity of the rotating masses,

$$W = k\,R^3 \qquad (74)$$

where k is the homology factor which represents the characteristic index of the series. From Equations 73 and 74, then

$$E = \frac{k\,R^2\,U^2}{1.34} \qquad (75)$$

For the special case of isodromic series where U is constant, Equation 75 takes the general form: $E = kR^2$. This relationship between the geometrical module R and the operational module E is another expression of the fundamental relationship given by Equation 1, *Part* 1.

As previously mentioned, an existing series of the type of governor under discussion offers an interesting case for examination. This series was developed on the basis of the foregoing criteria and obeys them with close approximation except for certain minor deviations as indicated in *Table* 17 where the fundamental data of the series have been collected. The last four columns on the right-hand side of the table give the series of operational and geometrical modules, reduced to their unitary values, and the corresponding series ratios.

The series of operational modules may be defined as being "roughly rational." Although the term ratios diminish along the series, the pattern is one of marked irregularity, as shown by the curve plots in *Figs.* 36 and 37*a*. In these charts, the unitary energy values and series term ratios have been graphically depicted.

In the first chart, *Fig.* 36, the abnormal characteristics of the series are indicated by the irregularity of the slopes of subsequent segments. In the second plot, *Fig.* 37*a*, these irregularities are even more strikingly demonstrated by the disorderly variations of the ordinates (series ratios).

A rational series, equivalent to the one just examined in range of application and number of terms, can be obtained with the planned progression, 32-13-B (*Table* 5, *Part* 2) if the last term is eliminated. This series, which is depicted graphically in *Figs.* 36 and 37*b*, is not afflicted with the irregularities of the first arrangement and is clear-

Table 17—Commercial Series of Centrifugal Speed Governors

Model No.	Mean Energy, E (lb)	Angular Speed, N (rpm)	Radius of Rotation, R (in.)	Linear Velocity, U (fps)	Progression of Operational Modules		Progression of Geometrical Modules	
					Term Value	Ratio	Term Value	Ratio
1	132	800	1.575	10.98	1	....	1	....
2	265	700	2.047	12.49	2	2	1.3	1.3
3	397	550	2.558	12.29	3	1.5	1.625	1.25
4	551	500	2.913	12.78	4.17	1.39	1.85	1.14
5	707	450	3.305	12.78	5.12	1.225	2.1	1.135
6	882	380	3.660	12.78	6.67	1.3	2.325	1.10
7	1103	350	4.134	12.78	8.33	1.25	2.625	1.13
8	1412	310	4.726	12.78	10.67	1.28	3.00	1.14
9	1930	280	5.354	13.11	14.58	1.36	3.40	1.13
10	2514	250	6.102	13.31	19.00	1.30	3.875	1.14
11	2912	220	6.694	12.85	22.00	1.16	4.25	1.10
12	3750	200	7.480	13.11	28.33	1.29	4.75	1.12

ly an improvement. At the same time, however, this series must not be considered as the most convenient simply because of its equivalent applicability and improved characteristics.

In evaluating the applicability and rationality of two equivalent series, judgment must be based primarily on the value of the ratios themselves, rather than on the number of terms and the regularity of ratio variations. Consider, for example, the first series examined. If, in the series of operational modules, a first ratio of 2 and a last ratio of 1.3 are considered as being commercially feasible, and if the adoption of these limit ratios leads to a smaller number of terms than in the original series, the new line with a smaller number of models will be better economically, and thus more rational.

Calculation of the reduced series can be readily accomplished, using the equations given in *Part* 2, from the following given data: First term, 1; last term, 28.3; first ratio, 2; and last ratio, 1.3. The calculated series has only 8 terms, instead of 12 as in the original series. This series is also shown graphically in *Figs.* 36 and *37c;* calculated values are given in *Table* 18.

The foregoing example suggests some considerations, commercial in nature, which may be extended to other similar cases. Consider, for comparison, two typical cases: (1) A company manufacturing governors for both internal use and sales and (2) an engine manufacturer producing speed governors only for use on its engine units. In the first case, many customer requests must be answered. There is the possibility of distributing fixed charges over a vast production operation, with the attendant advantages of organization on a mass production basis. Such conditions simultaneously require and permit the adoption of series with larger numbers of models than is convenient in the second case. For this reason, any series based on the number of terms (12) in the original series examined will, from the standpoint of rationality of progression, be convenient only for the specialized manufacturer of the first type. The engine manufacturer will have to adopt the 8-term series or another even more limited.

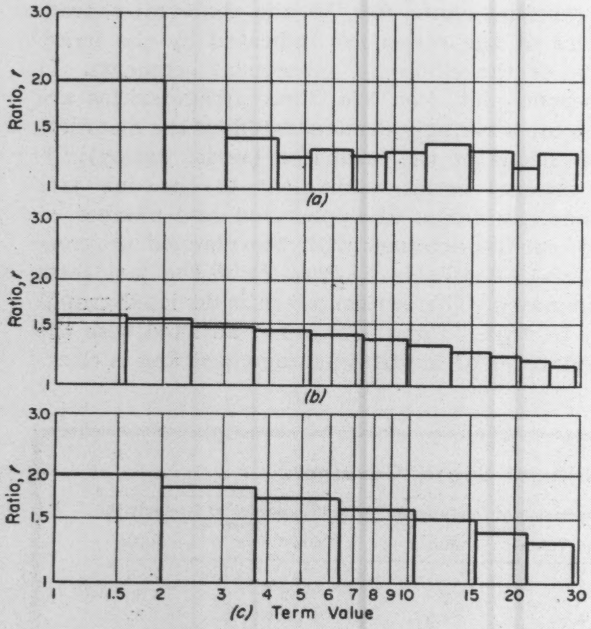


Fig. 37—Graphical analysis of line of centrifugal governors, corresponding to that of *Fig.* 36, showing plots of ratios of series of operational modules for: *a,* original 12-term series; *b,* modified 12-term series based on one of the planned progressions; and *c,* modified 8-term series based on a second-order progression

Table 18—Modified Governor Series

Model No.	Mean Energy, E (lb)	Progression of Operational Modules	
		Term Value	Ratio
1	132	1	....
2	265	2	2
3	492	3.72	1.861
4	854	6.45	1.734
5	1376	10.40	1.612
6	2065	15.61	1.501
7	2887	21.80	1.397
8	3750	28.33	1.3

Indirect Turbine Regulators: An example of a case where ordinary geometrical progressions are preferred over those of the second order for series planning is furnished by certain servomotor-tachometric controllers of the type used on hydraulic turbines. In this discussion, attention will be confined to one of the simplest and most common types in use, *Fig.* 38.

The capacity of these regulators is equal to the work performed, or expressed in equation form,

$$E_r = \frac{V_p\,p}{12} = \frac{\pi\,D^2\,lp}{48} = 0.0655\,D^2\,lp \quad \ldots\ldots\ldots (76)$$

where E_r = work performed by the regulator, ft-lb; V_p = piston displacement, cubic inches; p = normal oil pressure, psi; D = cylinder diameter, inches; and l = piston stroke, inches.

For these units, the selection of geometrical and operational modules is readily apparent. The former is given by the piston displacement, V_p, and the latter by the work quantity, E_r. If oil pressure is constant, an exact proportional relationship exists between the two modules.

In determining an appropriate series arrangement, apparently only those considerations relating to general organization and commercial requirements can prevail. Nevertheless, there is a characteristic, peculiar to this particular case, which can and must serve as a guide.

On the basis of total cost of a hydraulic turbine generating set, the controller unit takes on a proportional importance that increases rapidly as the capacity of the set decreases. Thus, for turbine sets of small capacity, it is convenient to select a controller with a work capacity which does not greatly exceed the required amount. If the intervals in the initial portion of the governor series are too large, selection of a unit that is too expensive may be forced by application requirements. To avoid this undesirable condition, a series must be determined in which the tendency toward high initial ratios is compensated. This compensation may be readily obtained through the use of an ordinary geometrical progression which might well be one of the standard preferred number series.

For the term ratios, which now become constant along the entire series, the following criteria must be adopted. Servomotor controllers are reciprocating machines in which the geometrical module is given by the cylinder diameter, at least in the usual case where there is a proportional stroke-to-diameter relationship. Thus, D is proportional to $\sqrt[3]{E_r}$, and the ratio of the progression of diameters is equal to the cube root of the ratio of the progression of regulator work capacities. If the ASA 5-series of preferred numbers, which has a ratio of 1.58 (*Table* 3, *Part* 2), is adopted for the series of operational modules, the corresponding geometrical module series will then have a ratio of $\sqrt[3]{1.58} = 1.16$. This ratio falls within the range of maximum convenience which was established in *Part* 1.

Assume a series of controllers is to be developed in which the range of work capacities is 500 to 10,000 ft-lb. Adopting the 5-series of preferred numbers and using limiting term values of 630 and 10,000 gives the following 7-term progression: 630, 1000, 1600, 2500, 4000, 6300, 10,000. From this series of controller work capacities, the series of displacements may be directly determined by means of Equation 76. The series of diameters and strokes may then be calculated from the equations developed in the preceding section for single-cylinder, single-acting reciprocal machines. In these calculations, the constant stroke-diameter ratio must be pre-established as a basis of the fundamental model design.

Final Remarks: The foregoing discussion clearly shows how a careful and critical analysis must constantly rule any study of machine series. Throughout this series of articles, it has been demonstrated that in the great majority of cases second-order progressions must be the mathematical guide to rational series planning. Despite this emphasis, the classical Renard's, or preferred-number series certainly has valid applications in some series planning problems, as demonstrated by the final example.

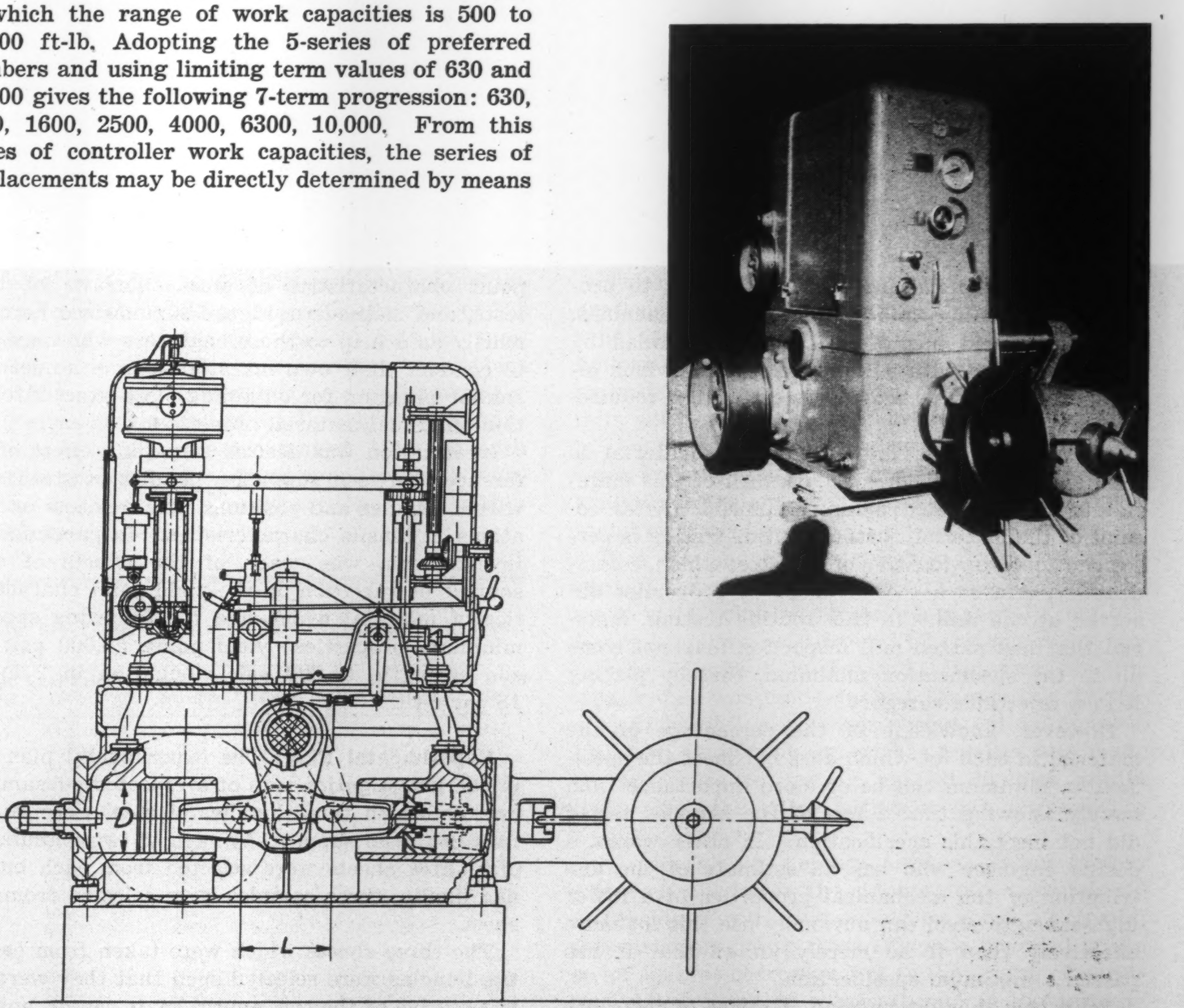
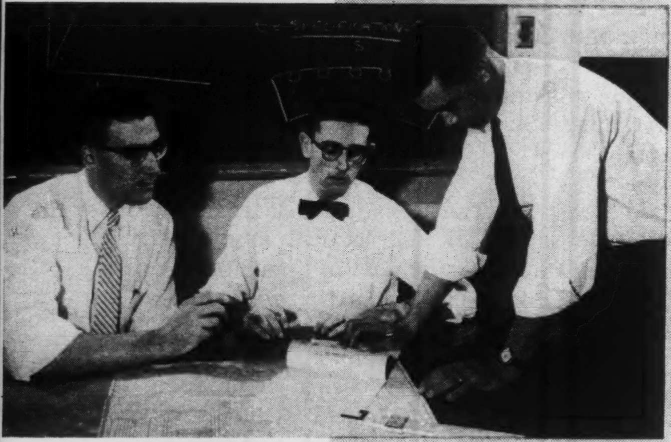


Fig. 38—Typical servomotor controller design for use on hydraulic turbines. Photo, courtesy P. Merlini & Hijos, Buenos Aires

Obtaining Accurate Mechanical Property Data on HIGH-STRENGTH



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THROUGHOUT industry the trend is to produce smaller and more efficient machines. This trend has often been accompanied by the use of steel with a high yield point, which allows the use of less mass to meet design requirements.

At Westinghouse, high yield-point material is used extensively in new designs. All of this material is mill inspected before shipment. After receipt of the material, further routine testing is performed to verify identity of the steel which, coincidentally, affords a second check of properties observed at the mill. In this routine testing, material that has passed mill inspection may not come up to the specification minimum, thereby placing it in a rejectable category.

However, knowledge of the percentage of the material in each lot which does not meet the specification minimum can be of more importance than merely knowing that a few of the samples tested did not meet this specification. In other words, a design engineer who has an estimate of the distribution of the mechanical properties of a lot of high-strength steel can obviously use this lot more effectively than if he merely knows that it has passed a minimum specification.

With this thought in mind, a series of tests has been made to estimate the distribution of mechanical properties in typical lots of steel; in particular, to investigate the sources of variation of yield-point characteristics of steel. Results of these tests, and methods used, are summarized here primarily as a help to those engineers who may wish to conduct their own investigations or to set up a similar program for obtaining more exact information on actual material properties.

Information was desired regarding effect of differences between suppliers, bundles of steel, sheet within bundles and positions within sheets on variations in tensile characteristics. In particular, an investigation was made of the effects of these sources of variation on the yield point characteristics of material which had the following specified minimum properties: yield point, 55,000 psi; tensile strength, 65,000 psi; elongation in 2 inches, 18 per cent.

Experimental Plan: The experimental plan used in the investigation was of a repeated subsampling type in which three bundles of steel were selected from material supplied by each of two manufacturers; three sheets were selected from each bundle; and finally, three samples were selected from each sheet.

The three sheets which were taken from each of the bundles were selected such that they were representative of the top, approximate center, and bottom sheets in the bundle. This arrangement, in effect, gave a sample from the front, middle, and back end of a coil.

STEEL

A simple method for statistical determination of actual yield-point variation

Statistical Analysis: For the purpose of this discussion, only the yield point characteristics of the samples will be considered. *Table* 1 lists the sample designation and the corresponding yield point data. The sample designation or code number actually gives an account of the experimental history of the sample, e.g., the designation 1311 indicates that this specimen came from supplier No. 1, bundle No. 3, sheet No. 1, and position No. 1 within the sheet.

Table 1—Yield Points of Experimental Samples

Sample Number	Yield Point (psi)	Sample Number	Yield Point (psi)	Sample Number	Yield Point (psi)
2331	46,850	2213	47,500	1323	61,850
2223	49,300	1333	63,300	2312	57,150
1121	66,900	1111	63,350	2233	56.200
2221	50,150	1331	68,750	2121	56,100
2113	59,950	1112	67,150	1211	55,700
1313	72,350	2321	59,350	1132	62,900
2222	49,200	1223	61,500	2313	56,600
1312	69,400	2212	47,250	1212	70,950
2111	59,600	2133	56,600	1322	62,550
2112	60,200	1222	62,650	2311	55,950
2333	46,050	1221	61,300	1131	65,650
1232	67,700	2132	55,600	1133	68,600
1233	68,150	1332	69,900	1321	65,150
1122	70,650	2131	54,550	1213	65,250
1231	65,300	2322	61,700	2232	57,850
1123	59,850	1113	61,650	2122	55,650
2332	45,650	2323	59,050	2231	58,350
1311	83,250	2211	54,500	2123	53,550

These test results were analyzed by using the analysis of variance technique. By means of this type of analysis, the effects of the experimental factors can be measured with respect to unexplained or residual variation. Computational details will not be presented here but may be found in the *References*, which discuss experimental designs and the analysis of variance. Results of the analysis are summarized in the analysis of variance found in *Table* 2.

This statistical examination indicated the presence of a highly significant difference between the mean yield point values of the material from different suppliers, as indicated by the significant difference (*F*-ratio) in *Table* 2. The test for this significance was made against the also highly significant variation between sheets within bundles. The test against sheets within bundles was made in preference to testing against bundles within heats since the latter variation was not found to be significant.

At this point, perhaps, several other factors whose effects fall in the category of "unexplained" or "residual" variation should be noted. Actually, the variation due to these effects is included in the mean squares corresponding to the source of variation called "position within sheets" in the analysis of variance, *Table* 2. These factors are:

1. **Chemical Composition:** Generally speaking, each steel company marketing a high-strength steel

has its own formula for reaching the desired yield point level. These differences are inextricably mixed with differences between suppliers in the preceding analysis. There are, as well, differences in composition between samples from the same heat whose contribution to the variation is contained in the unexplained variation. No attempt was made in this analysis to determine the relationship between chemical composition and yield point.

2. **Rolling Practice:** Chemical composition is not the sole criterion of yield point. It acts in combination with possibly several other factors, one of which is the mill's rolling practice. Quite often, when desired strength levels are not reached, the steel will be strain-hardened by additional cold rolling on a temper mill. Another factor which may also affect the strength level of the steel is the coiling temperature on the hot strip mill. These factors, in general, may inflate the variation either between or within material from different suppliers.

Table 2—Analysis of Yield-Point Variance

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Between suppliers	1	1,911,140,000	1,911,140,000	30.4*
Bundles within suppliers	4	158,268,000	39,567,000	....
Sheets within bundles	12	755,242,200	62,936,900	7.45*
Positions within sheets	36	304,061,700	8,446,200	....

*Probability of so large an F-ratio occurring by chance alone is less than 0.001.

Nomenclature

μ = mean of the probability distribution of a universe

σ = standard deviation of the probability distribution of a universe

σ^2 = variance of the probability distribution of a universe

s = sample estimate of σ

s^2 = sample estimate of σ^2

t = deviation of a random variable from its mean divided by an estimate of the standard deviation; generally called the "t-statistic".

x_m = mean of the sample $(x_1, x_2, \ldots, x_n)$ and estimate of μ

Estimating Yield-Point Distribution: History of the yield-point characteristic has indicated that, considered as a random variable, its distribution is approximated by the normal distribution. Hence, in order to estimate the distribution of yield points in a lot, it is sufficient to determine the lot's mean and standard deviation. From the preceding analy-

Table 3—Per Cent of Values Above (Below) Specification

	4		6		8		10		13		16		20	
t	I*	II†	I	II	I	II	I	II	I	II	I	II	I	II
0.1	53.7	46.3	53.8	46.2	53.8	46.2	53.9	46.1	53.9	46.1	53.9	46.1	53.9	46.1
0.2	57.2	42.8	57.5	42.5	57.6	42.4	57.7	42.3	57.8	42.2	57.8	42.2	57.8	42.2
0.3	60.8	39.2	61.2	38.8	61.4	38.6	61.4	38.6	61.5	38.5	61.6	38.4	61.6	38.4
0.4	64.2	35.8	64.7	35.3	65.0	35.0	65.0	35.0	65.2	34.8	65.2	34.8	65.3	34.7
0.5	67.4	32.6	68.0	32.0	68.4	31.6	68.5	31.5	68.6	31.4	68.8	31.2	68.8	31.2
0.6	70.5	29.5	71.2	28.8	71.6	28.4	71.8	28.2	72.0	28.0	72.0	28.0	72.2	27.8
0.7	73.2	26.8	74.2	25.8	74.6	25.4	74.0	26.0	75.2	24.8	75.2	24.8	75.4	24.6
0.8	75.8	24.2	76.9	23.1	77.4	22.6	77.7	22.3	78.0	22.0	78.1	21.9	78.2	21.8
0.9	78.2	21.8	79.5	20.5	80.1	19.9	80.4	19.6	80.5	19.5	80.8	19.2	81.0	19.0
1.0	80.4	19.6	81.7	18.3	82.4	17.6	82.7	17.3	83.0	17.0	83.2	16.8	83.4	16.6
1.1	82.3	17.7	83.8	16.2	84.6	15.4	85.0	15.0	85.3	14.7	85.5	14.5	85.6	14.4
1.2	84.1	15.9	85.7	14.3	86.4	13.6	86.8	13.2	87.2	12.8	87.4	12.6	87.6	12.4
1.3	85.6	14.4	87.2	12.8	88.0	12.0	88.6	11.4	89.0	11.0	89.2	10.8	89.4	10.6
1.4	87.0	13.0	88.8	11.2	89.8	10.2	90.2	9.8	90.5	9.5	90.7	9.3	90.9	9.1
1.5	88.2	11.8	90.2	9.8	90.9	9.1	91.3	8.7	91.7	8.3	92.0	8.0	92.2	7.8
1.6	89.5	10.5	91.2	8.8	92.0	8.0	92.4	7.6	92.8	7.2	93.2	6.8	93.4	6.6
1.7	90.4	9.6	92.1	7.9	93.0	7.0	93.5	6.5	94.0	6.0	94.4	5.6	94.6	5.4
1.8	91.2	8.8	93.0	7.0	94.0	6.0	94.6	5.4	95.1	4.9	95.3	4.7	95.5	4.5
1.9	91.8	8.2	94.0	6.0	95.0	5.0	95.4	4.6	95.8	4.2	96.0	4.0	96.2	3.8
2.0	92.8	7.2	94.8	5.2	95.6	4.4	96.0	4.0	96.4	3.6	97.2	2.8	96.8	3.2
2.2	94.0	6.0	95.8	4.2	96.6	3.4	97.2	2.8	97.8	2.2	97.7	2.3	97.8	2.2
2.4	95.2	4.8	96.8	3.2	97.6	2.4	97.8	2.2	98.2	1.8	98.4	1.6	98.6	1.4
2.6	95.8	4.2	97.8	2.2	98.0	2.0	98.4	1.6	98.8	1.2	99.0	1.0	99.1	0.9
2.8	96.4	3.6	98.0	2.0	98.6	1.4	99.0	1.0	99.2	0.8	99.3	0.7	99.4	0.6
3.0	97.0	3.0	98.3	1.7	99.0	1.0	99.2	0.8	99.4	0.6	99.5	0.5	99.6	0.4
3.2	97.5	2.5	98.7	1.3	99.2	0.8	99.4	0.6	99.6	0.4	99.6	0.4	99.6	0.4
3.4	97.8	2.2	99.0	1.0	99.4	0.6	99.6	0.4	99.6	0.4	99.7	0.3	99.8	0.2
3.6	98.0	2.0	99.2	0.8	99.5	0.5	99.6	0.4	99.7	0.3	99.8	0.2	99.8	0.2
3.8	98.2	1.8	99.4	0.4	99.6	0.4	99.6	0.4	99.8	0.2	99.8	0.2	99.9	0.1
4.0	98.4	1.6	99.5	0.5	99.6	0.4	99.7	0.3	99.8	0.2	99.9	0.1	99.9+	0.1—
4.2	98.6	1.4	99.6	0.4	99.6	0.4	99.8	0.2	99.9	0.1	99.9+	0.1—	99.9+	0.1—
4.4	98.8	1.2	99.6	0.4	99.7	0.3	99.8	0.2	99.9+	0.1—	99.9+	0.1—	99.9+	0.1—
4.6	99.0	1.0	99.6	0.4	99.8	0.2	99.9	0.1	99.9+	0.1—	99.9+	0.1—	99.9+	0.1—
4.8	99.1	1.0	99.6	0.4	99.8	0.2	99.9+	0.1—	99.9+	0.1—	99.9+	0.1—	99.9+	0.1—
5.0	99.2	0.8	99.6	0.4	99.8	0.2	99.9+	0.1—	99.9+	0.1—	99.9+	0.1—	99.9+	0.1—

*Per cent of values $\geqq$ specification if $x_m >$ specifications.

†Per cent of values $\geqq$ specification if $x_m <$ specification.

sis, it is quite clear that the means from lot to lot can differ significantly. Although not a result of the analysis, it also seems quite reasonable to believe that the variation from lot to lot over a period of time might be subject to change.

By assuming that yield-point distributions are in all cases approximated by normal distributions, with possibly differing means and variances, the percentage of the yield points in any lot which are greater than the specification minimum can be estimated by the following procedure.

A sample of n specimens is selected from sheets taken at random from the lot and is tested for the yield points (x_1, x_2, . . ., x_n). Estimates of the lot's mean, μ, and variance, σ^2, can be obtained from this set of values by (see *Nomenclature*):

$$x_m = \frac{1}{n}\,(x_1 + x_2 + \ldots + x_n)$$

and

$$s^2 = \frac{1}{n-1}\,[(x_1 - x_m)^2 + (x_2 - x_m)^2 + \ldots + (x_n - x_m)^2]$$

Selecting the sheets at random permits the estimate of the variance to contain essentially two components: that component due to sheet-to-sheet variation, and that due to position within the sheets.

Since the normal distribution is completely defined by μ and σ^2, the estimates x_m and s^2 define the approximate distribution of yield points of the lot. However, a more useful description of this distribution is obtained by including the percentage of the yield points which may be expected to fall at or above the specification minimum. This percentage can be found by finding the probability

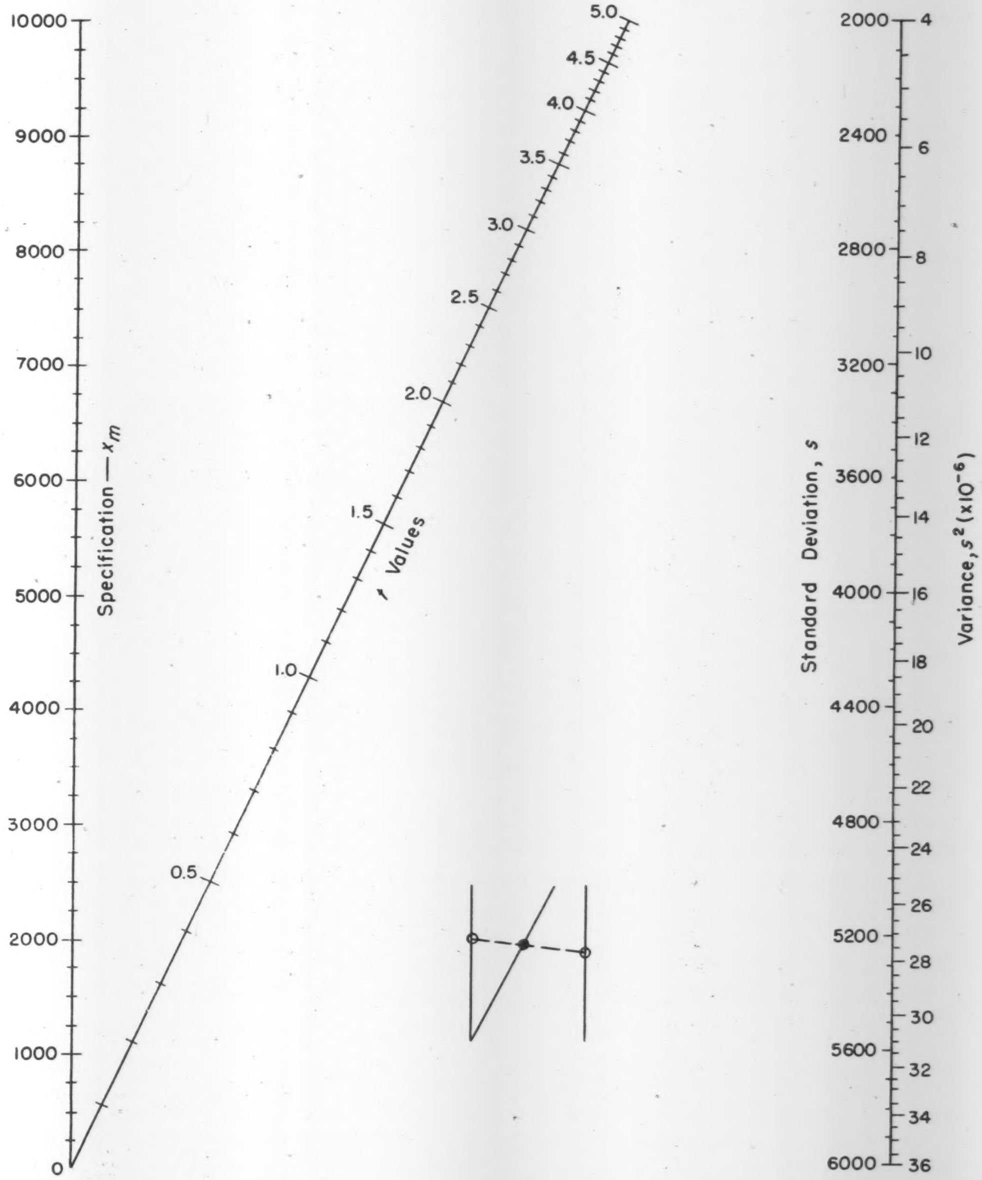

Fig. 1 — Alignment chart for determining *t*-value used in estimating actual distribution of tensile properties of steel

of t being greater than or equal to the "t-statistic",

$$t = \frac{\text{specification} - x}{s}$$

Tables giving this or some associated probability can be found in the appended *References*. Since the task of determining this probability becomes a rather repetitive one, use has been made of an alignment chart, *Fig.* 1, and some tabulated probabilities, *Table* 3.

Use of this alignment chart and the table of probabilities should be sufficiently explained by considering an example.

Suppose that for a lot of high-yield steel, a sample of eight specimens has a mean yield point $x_m = 60{,}000$ psi and a variance $s^2 = 16 \times 10^6$ (or standard deviation $s = 4000$ psi). If the specified minimum yield point of this material is 55,000 psi, the absolute difference between the specification minimum and the lot mean is

$$\text{specification} - x_m = 55{,}000 - 60{,}000 = 5000 \text{ psi}$$

On the alignment chart a corresponding t-value of 1.25 is read. Once the t-value is known, *Table* 3 can be used to obtain the desired probability or percentage.

Since a sample of eight specimens was used to obtain x_m and s^2, the per cent of the distribution above the specification minimum is obtained by using, in *Table* 3, column I, under sample size 8. In this case, $t = 1.25$ falls between the values 1.2 and 1.3. Percentages corresponding to these t-values are 86.4 and 88.0. Linear interpolation gives the percentage value corresponding to $t = 1.25$ as 87.2 or approximately 87.

Thus, for a lot whose mean yield point is 60,000 psi and whose standard deviation is 4000 psi, as determined from a sample of eight specimens, it is estimated that 87 per cent of the lot will have yield points greater than or equal to the specified minimum yield point of 55,000 psi.

Conclusions: Customary tensile tests at the steel mill do not give a complete picture of yield-point variation. While all tests at the mill can be above the specification minimum, further testing may indicate some yield point values to be below the minimum. A specification, while important in establishing standards, should not be considered as an iron-clad guarantee of properties. More attention should be paid to the fact that normal fluctuations in material properties are always present. Rather than reject material on the basis of minimum properties, the design engineer should consider the expected distribution of the mechanical properties. Knowledge of the maximum stress, safety factor, *and* the possible variation in mechanical properties should enable engineers and designers to set up reasonable requirements that might be satisfied by material on the minus side of a specification.

At the same time, it is felt that steel suppliers should begin to consider acceptance of specifications in which properties are specified on a statistical basis. Experience has shown that the standard of two tests per heat does not even begin to describe accurately the mechanical properties of the material. If steel is purchased according to a specification that is set up with respect to average properties and acceptable limits of the variation associated with these properties, suppliers will find this approach to be to their advantage. Instead of having material rejected because it fails to meet a specification minimum, they may, by means of a statistical analysis, show the customer that a desired percentage of the material will meet a given requirement if the specification properties have been stated on a statistical basis.

REFERENCES

1. W. Cochran and G. Cox—*Experimental Designs*, John Wiley & Sons, New York, 1950.
2. R. A. Fisher—*Design of Experiments*, Oliver and Boyd, London, 1949.
3. O. Kempthorne—*Design and Analysis of Experiments*, John Wiley and Sons, New York, 1952.

Spring Correction Simplified

STRESS correction factor, K, for helical round-wire compression springs or tension springs, otherwise known as the "Wahl correction factor," is given by:

$$K = \frac{4c - 1}{4c - 4} + \frac{0.615}{c}$$

where c is the "spring index," that is, $c = 2r/d$ or the ratio of body diameter to wire diameter.* Examination of this form shows that when c is given, the formula requires three slide-rule operations and three summation operations to yield the value of K.

A method of simplifying slide-rule computation is by rewriting the formula as follows:

$$K = \frac{c - 1/4}{c - 1} + \frac{0.615}{c}$$

$$= 1 + \frac{0.75}{c - 1} + \frac{0.615}{c}$$

After revision, the formula requires only two slide-rule operations and two summations. Since c is not usually an integer, better accuracy will result, considering slide rule limitations. — ROBERT A. VANSLETTE, *Doelcam Corp., Newton, Mass.*

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*A. M. Wahl—*Mechanical Springs*, Penton Publishing Co., Cleveland, O., 1944, Page 37.

They Say . . .

"It is surprising how much money can be saved by watching even so small an item as a bolt. The big things somebody else has already discovered and done something about; it is the little things that, even though they take a lot of patience, result in savings."—WARREN C. MACFARLANE, *President and General Manager, Minneapolis-Moline Co.*

MACHINE DESIGN
Data Sheet

How to Find Reactions of Beams with Nonuniform Loading

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REACTIONS at the supports of nonuniformly loaded beams can be easily found by the methods shown in this data sheet. The methods are based on the proposition that two resultants are better than one.

The resultant of a distributed load may be either

1. A single force along a certain line which must be determined
2. A couple, or
3. Two forces along predetermined parallel lines, which will have the same effect, mechanicswise, as the original distributed load.

It may not be both the first and second conditions in any one case, but the third will always give a desired effect no matter whether the alternative be a force or a couple.

Simplest case of a distributed load is shown in *Fig.* 1. Conventional attack is to find the single resultant, *Fig.* 1*a,* then take moments to find the reactions at the two supports. Here the resultant is midway between the supports and the reactions are easily found by inspection; but other cases are more difficult. The methods to be presented here give a direct solution for the resultant at each of the two ends of the loaded section, *Fig.* 1*b.* Magnitude and location of the single resultant W can be skipped.

For the more difficult problems of distributed but nonuniform loading the method is to find an equation for the load per unit length. Simplest of these is the linear relation $w = a + bx$, where x is the position on the beam measured from the left-hand support, at which the unit loading is w, and a and b are constants, *Fig.* 2.

To find the two resultants take moments about the left and right-hand positions:

$$M_{x=0} = \int_0^L wx\,dx - R_R L$$

$$M_{x=L} = R_L L - \int_0^L w(L-x)\,dx$$

Since these moments are each equal to zero,

$$R_R = \frac{1}{L}\int_0^L wx\,dx \quad \ldots\ldots\ldots\ldots (1)$$

$$R_L = \frac{1}{L}\int_0^L w(L-x)\,dx \quad \ldots\ldots\ldots\ldots (2)$$

Substituting for w its value $w = a + bx$ and

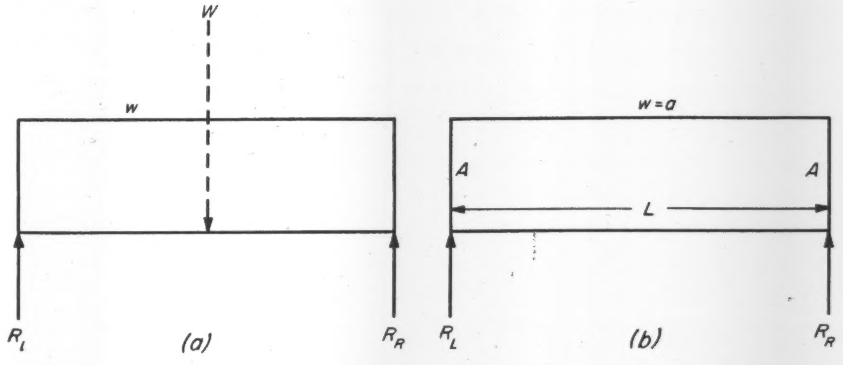


Fig. 1—Simple beam with uniform load w pounds per unit length. Single resultant is W pounds, acting at midpoint, *a.* Two resultants acting support points, *b,* are more directly useful

integrating Equations 1 and 2, the resultants are found to be

$$R_R = \frac{aL}{2} + \frac{bL^2}{3}$$

$$R_L = \frac{aL}{2} + \frac{bL^2}{6}$$

To find the coefficients a and b in the equation which fits the loading, the values of two ordinates A and B at the ends are determined. Since $w = A$ when $x = 0$, and $w = B$ when $x = L$ the coefficients are found to be

$$a = A$$

$$b = \frac{B - A}{L}$$

Substituting these values in the foregoing equations for the right and left-hand resultants,

$$R_R = \frac{L}{6}(A + 2B)$$

$$R_L = \frac{L}{6}(2A + B)$$

Total load W is the sum of the two resultants

$$W = R_L + R_R \quad \text{(3)}$$

Location of the single resultant, W, if needed may be found from simple moments. Thus, if L_L is the distance of the line of action of W from the left end

$$WL_L = R_R L$$

from which

$$L_L = \frac{R_R L}{W} = \frac{R_R L}{R_L + R_R} \quad \text{(4)}$$

More complex distributions of loading call for equations with second, third or even fourth-power terms. Thus, if the loading curve is not a straight line, as it is in *Fig.* 2, a good approximation might be a parabola, *Fig.* 3. This particular case responds to Simpson's Rule for figuring total load. If the varying load has three known ordinates A, B and C spaced apart equally, it is possible to fit a curve of the form $w = a + bx + cx^2$ through the three ordinates.

Procedure here is precisely the same as before, and may be generalized as follows:

1. Substitute equation for w in Equations 1 and 2 and solve for R_R and R_L
2. Set $w = A$ when $x = 0$, $w = B$ when $x = L/2$ and $w = C$ when $x = L$, in the equation for w and solve the resulting simultaneous equations for a, b and c in terms of A, B and C
3. Substitute back into equations for R_R and R_L so that these resultants are expressed directly in terms of A, B, C and L
4. If necessary, find total load W by adding R_L and R_R, Equation 3.

Results of the foregoing steps are given in *Table* 1, which shows the values of a, b and c in terms of A, B and C, and in *Table* 2, which lists the resultant loads and total load.

Table 1—Equations for Curve Fitting

Illustration	Fig. 1	Fig 2	Fig. 3	Fig. 4	Fig. 5
Type of Curve	a	$a + bx$	$a + bx + cx^2$	$a + bx + cx^2 + dx^3$	$a + bx + cx^2 + dx^3 + cx^4$
Number of Ordinates Needed	1	2	3	4	5
$a =$	A	A	A	A	A
$b =$	0	$\frac{B-A}{L}$	$\frac{-3A+4B-C}{L}$	$\frac{-11A+18B-9C+2D}{2L}$	$\frac{-25A+48B-36C+16D-3E}{3L}$
$c =$	0	0	$\frac{2(A-2B+C)}{L^2}$	$\frac{9(2A-5B+4C-D)}{2L^2}$	$\frac{2(35A-104B+114C-56D+11E)}{3L^2}$
$d =$	0	0	0	$\frac{9(-A+3B-3C+D)}{2L^3}$	$\frac{16(-5A+18B-24C+14D-3E)}{3L^3}$
$e =$	0	0	0	0	$\frac{32(A-4B+6C-4D+E)}{3L^4}$

It now becomes evident that it is simpler to find the two resultants for the ends of the loading than to work out the total resultant and the location of its line of action.

Expansion of Simpson's Rule to cover four or five ordinates follows the same procedure. The fitting curve for four equally spaced ordinates A, B, C and D is of the form $w = a + bx + cx^2 + dx^3$. The coefficients a, b, c and d are given in *Table* 1, and the resultant forces in *Table* 2. As the number of evenly spaced ordinates goes up, the number of terms in the fitting curve goes up. And the work of figuring the equivalent of Simpson's Rule becomes extremely laborious. The results are

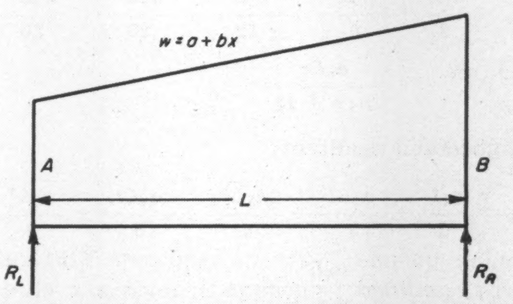
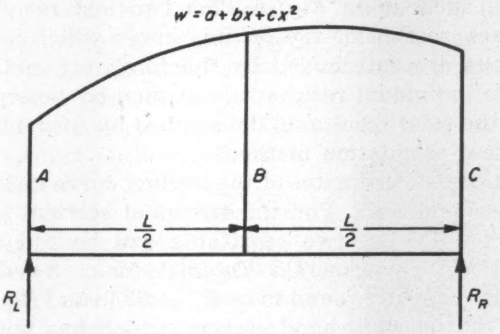


Fig. 2 — Above — Beam with load that increases in straight-line fashion from one end to the other. Equation to the loading curve is $w = a + bx$, which can be expressed in terms of two ordinates A and B

Fig. 3—Below—Loading curve in the form of a parabola. Values of three equally spaced ordinates A, B and C must be known to specify the loading curve equation



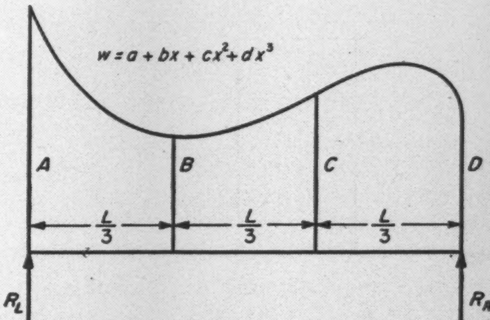


Fig. 4—Above—Loading curve requiring a third-degree equation. Four equally spaced ordinates A, B, C and D must be known. Results are given in *Tables* 1 and 2

Fig. 5 — Below — Fourth-degree equation loading curve, which may be useful where load variation is extremely irregular

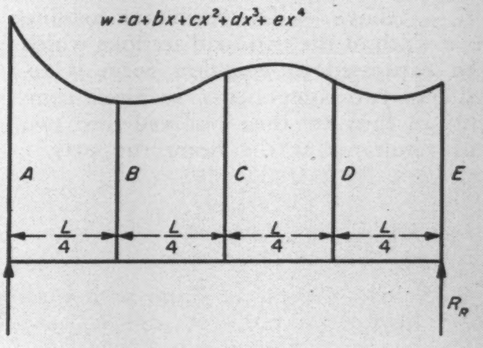


Table 2—Resultants for Five Types of Beam Load Curves

Load Curve	Fig. 1	Fig. 2	Fig. 3	Fig. 4	Fig. 5
$R_L =$	$\frac{AL}{2}$	$\frac{L}{6}(2A+B)$	$\frac{L}{6}(A + 2B)$	$\frac{L}{120}(13A + 36B + 9C + 2D)$	$\frac{L}{90}(7A + 24B + 6C + 8D)$
$R_R =$	$\frac{AL}{2}$	$\frac{L}{6}(A+2B)$	$\frac{L}{6}(2B + C)$	$\frac{L}{120}(2A + 9B + 36C + 13D)$	$\frac{L}{90}(8B + 6C + 24D + 7E)$
$W =$	AL	$\frac{L}{2}(A+B)$	$\frac{L}{6}(A + 4B + C)$*	$\frac{L}{8}(A + 3B + 3C + D)$	$\frac{L}{90}(7A + 32B + 12C + 32D + 7E)$

*This equation follows Simpson's rule, which is exact for parabolic curves.

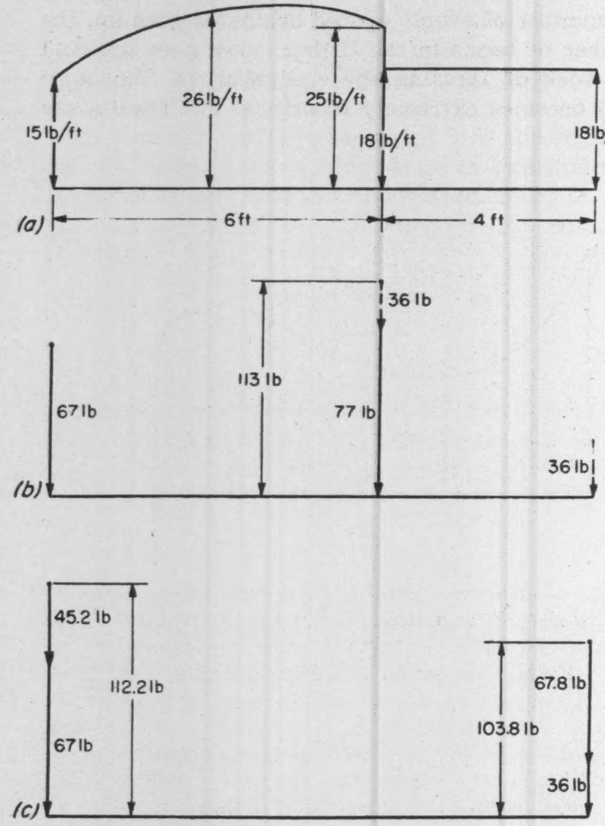
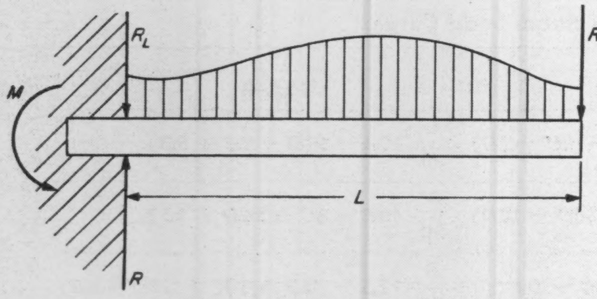


Fig. 6 — Above — Discontinuous loading curve, *a*. Each of the two load sections which can be expressed in equation form is resolved into two components, *b*. These components in turn are then resolved into two overall resultants at the beam supports, *c*

Fig. 7—Below—Cantilever beam with nonuniform load. Two resultants are R_L and R_R. Reaction force at support is $R = R_L + R_R$. Reaction moment is $R_R L$



given for a 5-ordinate curve in *Tables* 1 and 2.

If the loading curve can be fitted only by a curve of even higher degree, the necessary working equations can be derived from the following relations:

Loading curve:

$$w = a_1 + a_2x + a_3x^2 + a_4x^3 + a_5x^4 + \cdots + a_nx^{n-1}$$

Left-hand resultant:

$$R_L = \frac{a_1L}{2} + \frac{a_2L^2}{6} + \frac{a_3L^3}{12} + \frac{a_4L^4}{20} + \frac{a_5L^5}{30} + \ldots + \frac{a_nL^n}{n(n+1)}$$

Right-hand resultant:

$$R_R = \frac{a_1L}{2} + \frac{a_2L^2}{3} + \frac{a_3L^3}{4} + \frac{a_4L^4}{5} + \frac{a_5L^5}{6} + \ldots + \frac{a_nL^n}{n+1}$$

Total load:

$$w = a_1L + \frac{a_2L^2}{2} + \frac{a_3L^3}{3} + \frac{a_4L^4}{4} + \frac{a_5L^5}{5} + \ldots + \frac{a_nL^n}{n}$$

DISCONTINUOUS LOADING: The foregoing methods also can be applied to discontinuous loading situations, such as in *Fig.* 6. The two end resultants of each section of the loading curve which is continuous are determined by the foregoing methods. These individual resultants can then be superposed and the total resultants determined by conventional moment-calculation methods.

EXAMPLE: Ordinates of the loading curve in *Fig.* 6*a* are as indicated. For the left-hand section, which spans 6 ft, the two resultants can be calculated from the equations in *Table* 2 for a 3-ordinate curve. They are found to be $R_L = 67$ lb and $R_R = 77$ lb. For the right-hand section, which has uniform loading, the two resultants are each equal to 36 lb, *Table* 1. These two sets of resultants are superposed, *Fig.* 6*b*, and combined in *Fig.* 6*c*.

BEAM SUPPORTS: For beams simply supported at each end, the reactions are equal to the two resultants found by the methods presented here. If the supports are not at the ends, that is, if they do not coincide with the resultants, the reactions can be found by simple moments, using the two resultants.

Cantilever beam reactions are also calculated easily from the two resultants. The reaction force at the support is equal to the sum of the two resultants R_L and R_R. The reaction moment is equal to the resultant remote from the support times its distance to the support, *Fig.* 7.

Methods presented in this data sheet apply only to statically determinate beams.

Adhesive Bonding

. . . for joining metals and plastics

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GENERALLY speaking, an adhesive is a substance applied as a thin intermediate layer between two bodies for the purpose of joining these into a functional unit. The resultant joint must have sufficient strength to resist forces tending to cause separation of the parts. Practically all commercial adhesives are polymeric organic materials. Those adhesives which are employed in structural applications are most generally based upon synthetic resins. They are capable of hardening upon suitable reaction, generally in the presence of heat or catalyst. This process, termed curing or setting of the adhesive, is usually accompanied by the application of pressures in the range 10-300 psi. The epoxy-base adhesives are the outstanding exception, requiring only contact pressures, and are capable of being cured at room temperature.

Combined Joining Methods: While adhesive bonding is being employed in numerous cases in preference to other conventional fastening techniques, adhesives do not provide a "cure-all" for all fastening or joining problems. The most intelligent approach to selecting a suitable fastening technique is to decide which of the various methods is most satisfactory for a given application and to be able to employ all of these methods. It may often be advantageous to employ adhesive bonding in combination with another fastening method. For example, in aircraft aluminum honeycomb cores are first adhesive bonded to skins in the fabrication of parts such as wings, fuselages, etc. These bonded panels are then reinforced along the edges with rivets. Likewise, in missiles it has been found that large holes in pressurized tanks are best repaired by adhesive bonding a metal patch to the tank. Rivets are inserted around the patch essentially to fill holes used in clamping parts together during cure, *Fig.* 1. A structure repaired in this fashion, incidentally, has been successfully tested at temperatures as low as −300 F and under several pressure cycles up to 150 psi.

Some basic advantages of adhesive bonding are:

1. Joins dissimilar materials.
2. Eliminates need for high temperatures during joining.
3. Eliminates need for piercing materials.
4. Fastens parts to thin metal

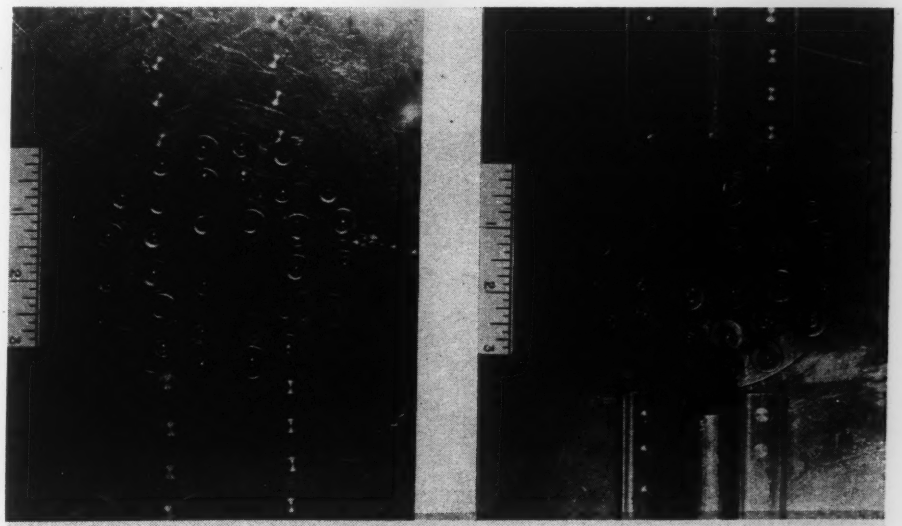

Fig. 1—Outside and inside of patch after bonding by curing at 315 F for one hour. In the final assembly, machine screws, washers and excess adhesive will be removed and rivet plugs installed

structures.

5. Provides leak-proof joints (sealing action).
6. Increases structural effectiveness through:
   a. Uniform stress distribution and increased service life.
   b. Reduced weight.
   c. Smooth surfaces and contours.
7. Reduces production costs.
8. Provides insulation and vibration-damping properties.
9. Resists corrosion.

Joining of Dissimilar and Thin Materials: Dissimilar metals and plastics, and thin materials, are advantageously joined with adhesives. In general, the mechanical mating of two dissimilar metals, such as aluminum and steel, is likely to result in severe corrosion over those areas in contact, especially in moist atmospheres. The adhesive bond provides a thin insulating layer preventing contact of dissimilar metals, and minimizing galvanic action with its accompanying corrosive effects.

In addition to corrosion problems, some pairs of metals, aluminum and magnesium are good examples, form brittle joints upon welding. Likewise impractical is welding of sheets of markedly different thicknesses. This factor is of little concern with adhesive bonding.

Use of a flux during soldering introduces the possibility of subsequent corrosion in the fabricated assembly, especially when residual flux cannot be readily removed. Adhesive bonding has eliminated this source of failure in joining corrugated brass sheet.

Thinner gage metals may be employed in adhesive-bonded structures than those used with other joining methods. Often the adhesive bond may be stronger than the parent metal. The metal need not be pierced or otherwise damaged during the joining operation.

An excellent practical example where the elimination of projections has proved to be an advantage of adhesive bonding is in the fastening of brake linings to steel brake shoes. Both the performance and useful life of the assembly have been enhanced.

Surface and Weight Considerations: A formed overlay skin ready to be bonded to a wing section is shown in *Fig.* 2. In this application, the problem was to build up the thickness of the wing section. However, since a smooth, aerodynamic surface was required and since the overlay was too thin for countersinking prior to riveting, an adhesive bond was preferred. Adhesives are valuable when smooth surfaces are required, whether from an aerodynamic standpoint or simply because of appearance, or when minimum weight is important.

Sealing Action: In the past, little mention has been made of the sealing action of adhesive bonds. Numerous difficulties are today being encountered in the fabrication of structures that are required to be airtight. Sometimes these structures must be sealed against high-pressure differentials and fuel vapors. The use of adhesives eliminates the need for sealants since there are no holes introduced into the structure during the bonding process.

Illustrated in *Fig.* 3 is one application of an adhesive bond to provide both sealing and joining simultaneously. The fabrication of a working model of a steam-heated tool is shown. Two steel plates were machined as shown and then joined so that steam passes through the channel. The adhesive employed here, CHT, was developed by North American Aviation, Inc., to meet the requirements of elevated temperature-resistant sandwich-type constructions. It is now being used in the fabrication of prototype missile components operating at temperatures in the order of 500-600 F.

Production Advantages: From a production standpoint adhesive bonding has much in its favor. Large areas can be joined in one bonding operation. Many adhesives can be applied by spraying or brushing, permitting the coating of large areas in a relatively short time. Most of the operations are automatic or at least semi-automatic, so that skilled workmanship is not critical. Production times, and likewise costs, have been reduced. Simplification of design is another factor often of importance, especially in miniaturized equipment such as employed in electronic apparatus.

Two aluminum tape recorder reels are shown in *Fig.* 4. One was fabricated by adhesive bonding of the flanges to the spool; in the other, the parts were joined by staking. This latter technique required additional design details and considerably more machining. In this particular application, it was essential that during the wrapping of the tape on the reel the flanges deflect less than 0.070-inch to maintain clearance between adjacent reels. It was found that if a 100-lb load was imposed by 0.75-inch of wrap, this 0.070-inch clearance could be closed in the case of the staked reel; on the other hand, the same loading condition on the bonded flange pro-

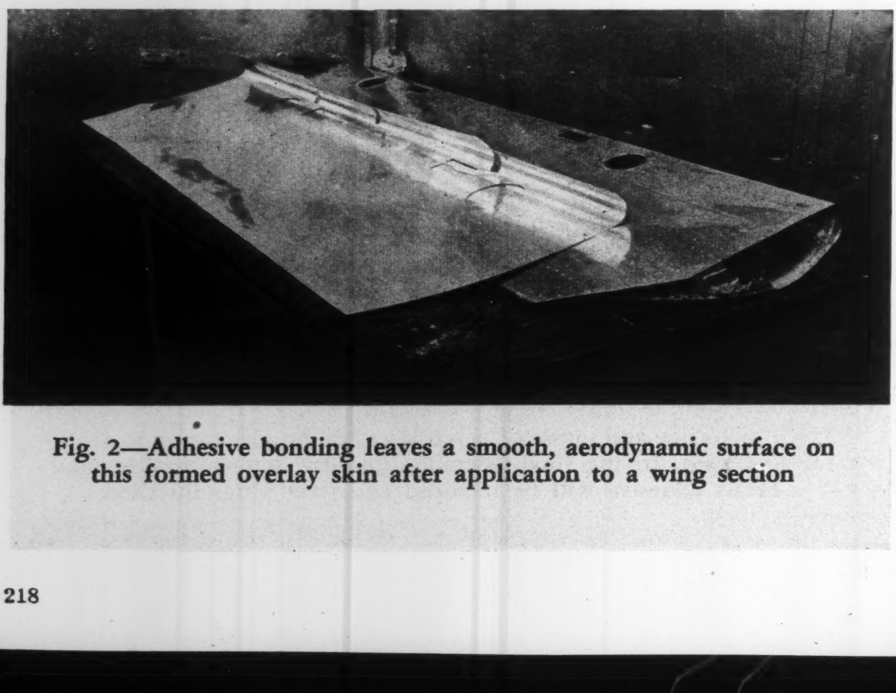

Fig. 2—Adhesive bonding leaves a smooth, aerodynamic surface on this formed overlay skin after application to a wing section

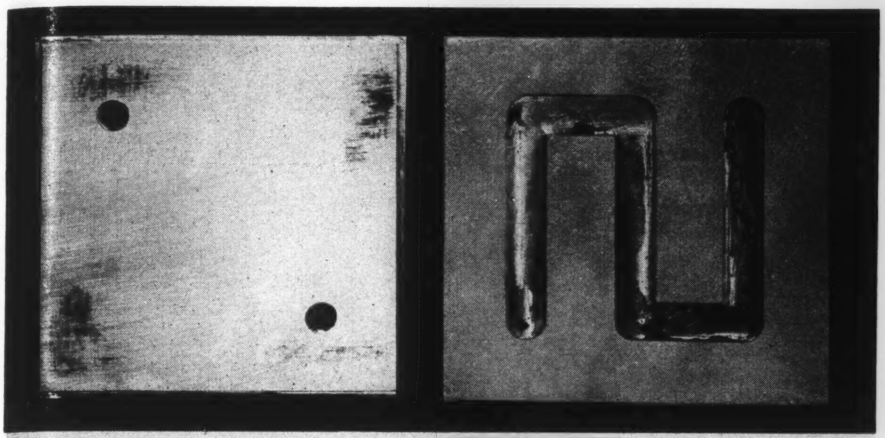

Fig. 3—Simultaneous sealing and joining of steam passages in this steam-heated tool is achieved through fabrication by adhesive bonding

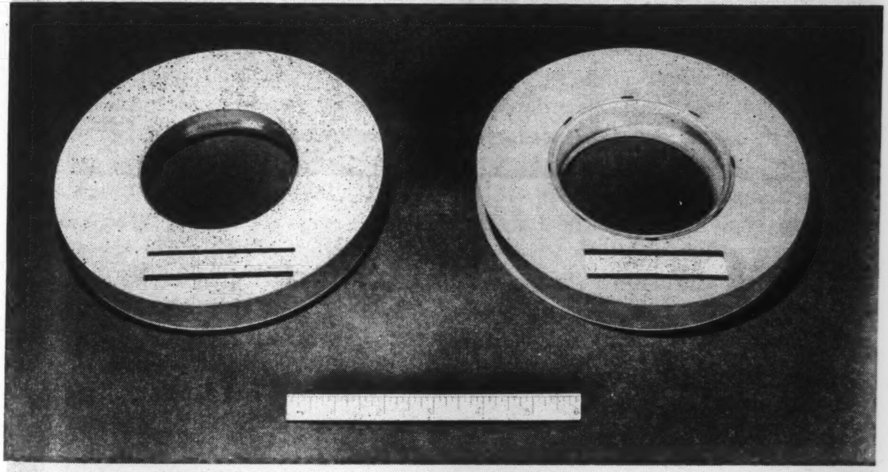

Fig. 4—Aluminum tape-recorder reel at the left was fabricated by adhesive bonding, the other by staking. Adhesive bonding produced more strength with fewer design details and less machining

duced only 0.015-inch deflection. Also, the adhesive-bonded reel was observed to be capable of sustaining about twice the bending load of the staked reel.

Structural Advantages: Structural advantages of adhesive-bonding are of considerable interest to the aircraft industry. An adhesive bond may be likened to a myriad of molecular-sized fasteners, each capable of withstanding applied forces. Thus, the bond can distribute loads uniformly over the entire area joined. The tendency for buckling in aircraft panels is largely eliminated when adhesives are used in the fabrication.

Sandwich Construction: The fabrication of sandwich-type construction provides one of the most promising applications for the use of adhesives. This new type of construction generally consists of a lightweight core material sandwiched between two relatively strong and thin skins or facings. Sandwich constructions are already being employed in primary as well as secondary structures in the aircraft and other industries in such applications as doors, bulkheads, partitions, floors, fuselage and wing skins, control surfaces, and radomes. Decorative applications, as in table tops, office partitions and skylighting, are now being considered involving such materials as window glass for facings. Indeed, the simplicity, uniformity, and light weight available through sandwich-type constructions are making these attractive not only to the aircraft, but to numerous industries engaged in nonmilitary products. Typical sandwich-type structure is illustrated in *Fig.* 5.

A wide variety of core materials are available, ranging from thermoplastic materials, such as Styrofoam and cellular cellulose acetate, to honeycombed aluminum and steel foils. A similarly wide choice of facing materials exist. The result is a tremendous flexibility in choice of materials, physical properties, and design.

The only economically practical method for joining these various core and facing materials is by adhesive bonding. Adhesives are used also in the splicing together of core sections and in the fastening of inserts and edgings to the sandwich. The tremendous growth of sandwich construction during the past decade has closely followed the rapid strides being made in the development of adhesives.

Bonding Procedures: Because the curing of the adhesive is a chemical reaction and because adhesion of the adhesive interlayer to the surfaces of the adherends is essential, the success of the joint is largely dependent upon proper application techniques. Usually the adhesive manufacturer or vendor will recommend optimum procedures which should be followed as closely as possible.

The procedures to be employed in adhesive bonding are summarized as follows:

1. Preparation of faying surfaces for bonding:
   a. Machining parts to match.
   b. Cleaning surfaces.
   c. Treating surfaces chemically.
   d. Masking adjacent areas.
2. Application of adhesive:
   a. Mixing of adhesive.
   b. Spraying, brushing, spreading of adhesive or cutting of adhesive film or tape.
   c. Removing excess adhesive.
3. Assembly of parts and curing of bond:
   a. Applying heat.
   b. Applying pressure.

Industrial Outlook: From an industrial standpoint, adhesive bonding is yet in its infancy. The present stage of development might well be described as the educational phase for industrial adhesives. Engineers and other technical personnel are now learning the why and how of adhesive bonding. Once they have gained confidence in this method, increasing numbers of applications will be found, and eventually engineers throughout industry will design specifically for adhesive bonding in order to utilize fully its vast potential.

From a paper entitled "Adhesives and Adhesive Bonding of Metals and Plastics" presented at the second Basic Materials Conference in Chicago, Ill., May, 1954.

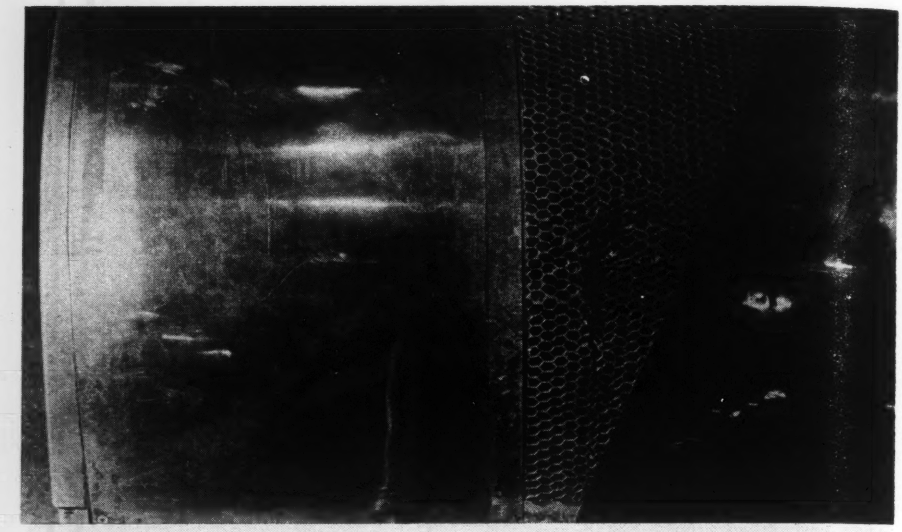

Fig. 5—Wing section with portion of skin removed to show aluminum honeycomb core. Adhesive serves to join skins to the core, the bonding being formed along the areas of the cell walls adjacent to the skins

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A Practical Approach to

Industrial Design

By Henry Dreyfuss
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A FIVE-POINT yardstick for good industrial design can be applied to every design problem, just as an auto mechanic applies a checklist to a balky motor. The points are:

1. Utility and safety
2. Maintenance
3. Cost
4. Sales appeal
5. Appearance

Let us consider these points.

Utility and Safety: Is the automobile easy to handle? Does the vacuum cleaner roll lightly and smoothly over the rug? Is the telephone grip comfortable? Is the turnoff switch easy to find when the alarm clock rings? Are the complicated controls of an airplane easy for the pilot to identify? On the Mergenthaler Linotype machine it was necessary to assure that the controls were placed within easy reach. For a Link Aviation testing device a great deal of time was spent insuring quick legibility. On the Mosler vault door for banks the legibility of the combination dial was made clearer.

Safety is a natural corollary to utility. Workers used to get badly injured on machinery. Today most hazards have been eliminated. On a Davidson duplicating machine the gear drive mechanism was shrouded so that the operator's hands and clothing would not get caught in it. On a Warner & Swasey turret lathe various colored knobs to denote emergency controls were used. The hydraulic control levers on National Supply's T 20 oil drilling rigs were placed within easy reach for a fast emergency getaway. Trade unions have been a great factor in promoting safety and designers frequently key their work to patterns the unions have developed.

Maintenance: How easy is it to wash a milk bottle or a frying pan? Can you find the elusive places to oil a sewing machine, or an electric shaver? How accessible are the cylinders on a diesel or the engines on a transport plane or the gear chains of a farm implement?

Maintenance must be an obvious thing. It must be easy to empty the grounds in a coffee maker or clean a plumbing fixture. The faucet handles on a Crane lavatory were mounted on ceramic pads so housewives could wipe around them and not have to dig into nasty cracks. The forms of an Ingraham clock and an RCA television set are very simple and easy to dust. The cover of the new small round Honeywell thermostat snaps off easily for quick access and maintenance of the interior apparatus. On the New York Times Stenofax duplicating machine the relays and working apparatus are on pull-out file drawer panels so the repair man can get to them easily.

Cost: No matter how preoccupied the designer is with the details of a new design, he is ever conscious of cost of manufacture and distribution. Even when it is not the over-riding factor, the designer tries to bring in a product under the estimate. There are two phases of cost of manufacture—tool cost and production costs. In items reproduced in comparatively small numbers, tooling costs are vital as they must be prorated over small production. In the design of many mass-produced items, however, contemplated production is so large that the manufacturer can comfortably write off tooling costs. In either case it is important to avoid increased production costs which are a continuing expense.

The designer may recommend additional tooling if by doing so production costs will be appreciably reduced. In the long run, on the production lines, an article made in one piece instead of two or three saves a great deal in assembly. Take for example, the cabinet of a table radio which formerly was an assembly of many pieces of wood, each laboriously individually shaped, sanded, glued together, and finished; today the cabinet is the result of a single molding process using a plastic compound. The cost of the mold necessary for this method of fabrication was more than offset by the savings on the assembly line.

The size of a product is also watched because by keeping it a quarter or half an inch smaller than originally planned, it is often found that more of them can be placed on a conveyor belt. The size and weight of a product also are important factors in cost of distribution.

Sales Appeal: Many persons think sales appeal and appearance are synonymous but they are not. Sales appeal is an elusive psychological value. It is the silent selling the product must do, over and above its eye appeal.

The product must express quality through unity of design, through texture, through simplicity and forthrightness. Soundlessly it proclaims the excellence of its concealed mechanism and the integrity of its manufacturer. Sales appeal, therefore, is an amalgam of how a product feels, how it operates, and the association of pleasant ideas it conjures up in the purchaser's mind.

Appearance: What does the product look like? Will a customer who sees it on a shelf in a store with half a dozen competing products single it out because of its appearance? Will it be remembered by the consumer who has briefly glimpsed it on TV or in a magazine ad?

It is our experience that faithful application of the first four points of this yardstick give the product nine-tenths of this appearance factor. The other tenth springs from the application of all we know of form, proportion, line and color. The whole emerges with vitality and with the assurance required in the highly competitive marketplace.

From a talk entitled "Industrial Design: the art of being practical" given at Harvard University Graduate School of Business Administration, Cambridge, Mass., in May, 1954.

Cermets

. . . materials for high-temperature service

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DURING the last decade, new high-temperature materials have been developed, consisting of combinations of metals with refractory compounds, to help fill the gap between the so-called superalloys and ceramics. The word "cermet" has been coined for these materials, and a rather large number of compositions is available at present to fulfill one or more design requirements.

Suitable refractory compounds include oxides, carbides, nitrides, borides and silicides. The oxides are poor heat conductors and electrical insulators and are exceedingly brittle, as are the other materials in this field.

Carbides, borides and silicides, however, are metallic in nature and have electrical and heat conductivities which are in some cases even better than those of their parent metals. Their behavior is similar in all respects to that of a metal and they are, in some cases, components of the high-temperature alloy materials which are presently in use. When isolated and used in much larger percentages they form the base materials for cermets. Although oxide materials in combination with metals are being investigated widely and are commercially available, this discussion is concerned mainly with the metallic refractories, or so-called hard metals, and especially carbide, borides and silicides of metals such as titanium, zirconium, molybdenum and chromium.

About a quarter of a century ago, the first cermet material was prepared. This material is the well known cemented carbide, consisting of tungsten carbide and cobalt, which is used in cutting tools. The structure of this tungsten carbide-cobalt material consists of a matrix of cobalt in which tungsten carbide particles are embedded. A hard material, tungsten carbide, is cemented together by a ductile metal, cobalt. Tungsten carbide is not oxidation resistant and is not usable as a high-temperature material. Its metallurgical structure, however, has been the leading idea for all the cermet materials.

The preparation of carbides and borides is relatively simple. The metals in powder form are mixed with carbon or boron of commercial purity and heated up to the reaction temperature, which is about 2800 F. In the case of titanium or zirconium, where the metal powder is strongly pyrophoric and therefore difficult to handle, the hydride powders can be substituted for the metal powders. The resulting compound—carbide, boride or silicide—is easily crushed and is then ready for use after it has been milled to the desired particle size. These powders are then mixed with the metal powder which is used as binder and processed according to powder metallurgical procedures, consisting essentially of pressing to shape and sintering. Sintering is the heating process which transforms the rather chalky, pressed compact into a metallic piece which has more or less the final properties. Pressing and sintering processes can be repeated to obtain higher density or they can be combined into one step which would mean that the pressing is done at high temperature. It is possible and sometimes necessary to add some organic materials in very small percentages which hold the powder together after pressing and which help to obtain sharp corners and close dimensions. These parts are then sintered at temperatures which are usually high enough to form a liquid phase, though this is not absolutely necessary. However, it helps accelerate the sintering process and in some cases is necessary to obtain the desired microstructure.

A considerable shrinkage occurs during the sintering process, which is absolutely necessary to obtain a dense part as the final product. The piece after compaction has a density in the neighborhood of only 60 to 70 per cent, sometimes even less, while the finished product should be 100 per cent dense or at least close to it. Shrinkage is between 15 and 20 per cent linearly for most of these cermet materials. If the process is well under control, this shrinkage is so exactly reproducible that dimensions after sintering can be kept to close tolerances.

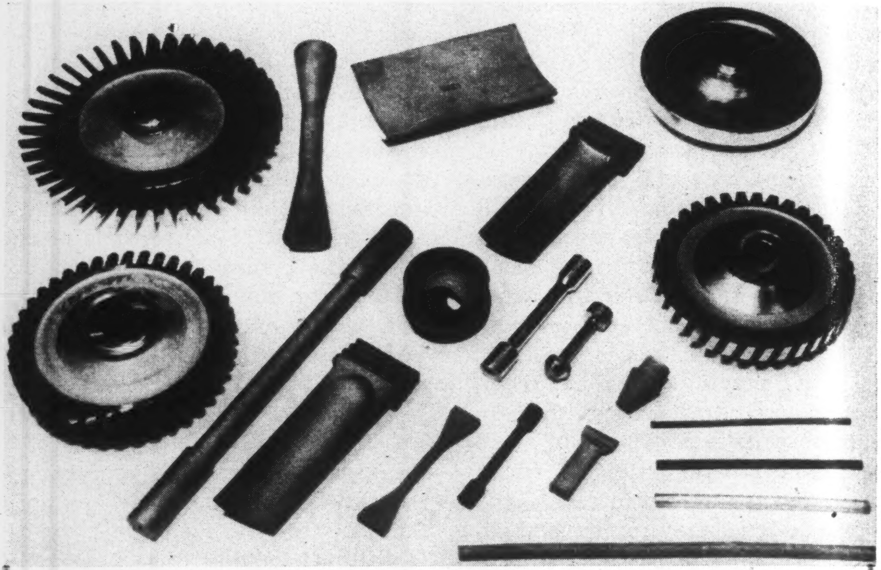


Fig. 1—Typical parts produced from titanium-carbide base cermet

Another interesting method of producing cermet materials is that of infiltration, which has recently been claimed to produce very good properties. In this case, the refractory material is sintered in the presence of only a very small amount of the binder metal. It then forms a rather porous skeleton which is reheated in contact with a slab of the infiltrant material. The compact and the metal are then heated to above the melting point of the latter, the metal melts and is forced by capillary action into the pores of the compact. It fills the pores entirely and by this method 100 per cent dense pieces can be produced. During this process the structure of the original hard metal compact is destroyed, and a new structure is formed which consists of more or less isolated particles suspended in the matrix of the metal.

Cermet materials receiving the most attention recently are:

1. Titanium carbide with nickel or cobalt binder, or with nickel alloys with chromium, molybdenum, or aluminum.
2. Boride base materials with or without the addition of materials such as chromium or nickel, using zirconium boride, chromium boride and molybdenum boride as the refractory components.
3. Silicide materials in the form of chromium or molybdenum disilicide.
4. Aluminum oxide and chromium materials.

Despite the variety of materials, the possibilities of combination are not as great as would appear on the basis of available compounds, especially if it is taken into account that most of the metals form a large number of borides and silicides with quite distinctive properties. The idea of the construction of cermets is to combine the metallic properties of the binder material with the refractory properties of the hard metal part. This consideration is, however, a simplification which is rarely or never quite correct. The reason is twofold. First, the two components react at high temperature to such a degree that in a number of cases new substances are formed which may have unknown or even undesirable properties. Second, the properties of such a compound material cannot be considered as the sum or the average of the properties of the individual materials.

The hard metal or metallic refractory which is most common for cermet application at present is titanium carbide. Titanium carbide has only fair oxidation resistance and two methods have been applied to improve the scaling resistance. One which has been used by Kennametal is the addition of other carbides, TaC and NbC, which form solid solutions with titanium carbide and improve the resistance to oxidation considerably. To these solid solutions, nickel or nickel alloys are added which give some ductility to the cermet and make it possible to produce it at convenient sintering temperatures. A well known composition of Kennametal is K152B, composed of 70 per cent carbide and 30 per cent Ni.

The second method is to add chromium to the nickel binder phase and thereby improve the oxidation resistance. This method has been used by the American Electro Metal Corporation and Firth Sterling Company. Such a composition is called WZ-12C and consists of 50 per cent TiC and 50 per cent binder, composed of nickel, cobalt and chromium. Many variations in these compositions have been tried to improve behavior at high temperatures. Generally, the strength is adequate and so is the oxidation resistance, but the materials are still quite brittle especially at room temperature, and the problem of improving the impact strength has not been solved. A selection of some parts made of TiC base cermet is shown in *Fig.* 1.

Other materials consist of chromium boride or zirconium boride with or without the addition of binder metals, such as chromium, and these materials have shown exceptionally high strength values at very high temperatures. They are also quite brittle but will, it is believed, form the basis for new materials, if still higher temperature requirements than 1800 F will be brought forward by engine designers.

The combination of borides or silicides with their parent metals (for instance, chromium silicide and chromium) is also a possible way to produce cermets. However, this is only possible for the lowest compound formed in the system. Chromium and silicon, for instance, form at least four different compounds together, and if chromium would be added to chromium disilicide, a reaction would occur forming a lower silicide, rather than preserving the combination of disilicide and chromium as a cermet material. Cermets on this basis have been produced and are being investigated at present for their physical properties and their stability at high temperatures. Chromium base materials have the advantage of being excellent in oxidation resistance although brittle.

Properties required for a high temperature material are high tensile strength, low creep, high stress-to-rupture strength, good heat shock resistance, low oxidation and the highest possible impact resistance. Characteristic curves of change of strength with temperature are shown for two cermet compositions in *Fig.* 2. For a 100-hour life, strengths of 12,000 to 25,000 psi can be obtained at 1800 F. This is satisfactory for almost all applications. The heat shock resistance of most of these materials is also quite good and 2000 cycles from 1800 F to room temperature have been withstood.

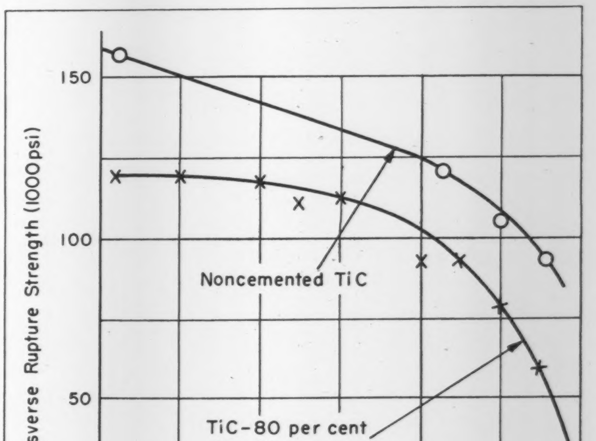
The property which is still preventing the wide application of these new high temperature materials is the impact strength at room and at high temperatures. In some cases the high-temperature impact resistance is considerably better, but this is the exception rather than the rule. The impact resistance of the best cermet materials available is roughly only 20 per cent of some of the superalloys which may even be considered brittle if compared with the ordinary metals.

For stationary applications some cermets would be usable immediately if the impact requirements were not too high. There, however, the competition of the cast and wrought superalloys is quite strong, and the superiority of the cermet material not so pronounced.

New and stronger materials as well as materials with better impact strengths are being developed constantly. It is, however, not to be expected that materials would ever be created which are comparable to the superalloys in impact behavior but have a higher temperature limit.

For short-time applications, such as rockets, some of the present day materials may be immediately applicable. Competition here is strong with standard ceramic substances. For rotating parts and machinery in which close dimensional tolerances are required at high temperatures, present designs and these materials do not fit together as yet. Even if cermet blading for a jet engine would fulfill all requirements for a rotating part, the shaft and the bearings would probably become considerably overheated due to the high heat conductivity which, in turn, makes the cermets

Fig. 2 — Curves of strength versus temperature for typical cermets



insensitive to heat shock.

The metallurgist is trying to come closer to the requirements of the present day designer with the development of materials with better impact resistance. On the other hand, the designer may have to change his thinking towards the use of more brittle materials, especially if he wants to push the temperature frontier beyond the 2000 F limit and into the range of 2400 F or still higher temperatures, which seem to be the goal for engines of the future.

From a paper entitled "Cermets—New High Temperature Materials" presented at the semi-annual meeting of the American Rocket Society in Pittsburgh, Pa., June, 1954.

Electrospark Machining

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IN VERY recent years, a whole family of machining newcomers have been uncovered. These are the electromachining methods. Their exploitation has been largely occasioned by the need for new methods to handle the stubborn machining problems presented in the processing of sintered carbides and superalloys.

Electrospark machining utilizes the breakdown of a dielectric to initiate a spark discharge and does not require the tool or electrode to touch the work to achieve machining efficiency. In fact, if the tool does touch the work it is undesirable and slows down the machining action. It is evident that the mechanical assemblage need only be sturdy enough to support the tool and workpiece and permit necessary positioning to achieve the accuracy that is desired in the finished product. The electrospark process commonly uses brass as a tool.

Basic Process: Electrospark machining can best be investigated by examining the mechanics of the process to determine exactly what happens as material is removed from a workpiece. The earlier examples of equipment utilized in performing spark machining consist of a well regulated source of dc power connected through a charging circuit to a capacitor, *Fig.* 1. The terminals of the capacitor are connected directly to the tool and work. The work is submerged under a dielectric bath, usually a hydrocarbon, and the tool is caused to approach the work along a predetermined axis by a movement of the tool holder. In its simplest form this type of machine strongly resembles a drill press except for the dielectric tank at the base of the machine column. The polarity of the dc source is so selected that the tool is negative and the work positive.

In actual practice, utilizing this type of machine, the voltage of the dc source may vary from 75 to 400 volts. Normally the higher voltages are associated with a so-called roughing cut and voltages of the order of 100 volts are used when making a finishing cut. The value of the capacitor will also vary with the type of operation, the larger capacities being associated with a roughing cut and the smaller values with a finishing operation. The feed during the cutting operation is, of course, of prime importance and is usually accomplished through a servodrive. The servodrive often obtains its error information from the average voltage that occurs between the tool and the workpiece.

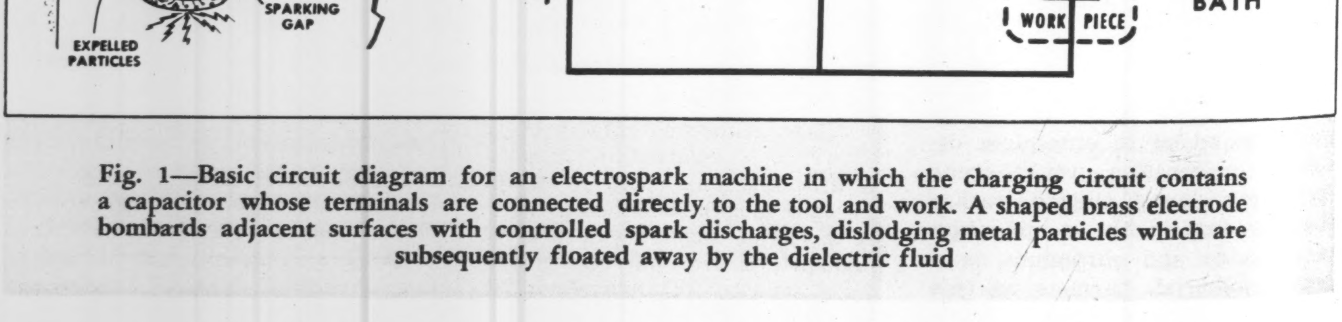

Fig. 1—Basic circuit diagram for an electrospark machine in which the charging circuit contains a capacitor whose terminals are connected directly to the tool and work. A shaped brass electrode bombards adjacent surfaces with controlled spark discharges, dislodging metal particles which are subsequently floated away by the dielectric fluid

If the circuitry is examined, it becomes apparent that the capacitor is utilized as an energy storage mechanism in which energy is stored over a relatively long period of time and is released in a period of short duration. If the charging circuit is purely resistive, the charging period is determined by the product of the values of the charging resistance and the energy storage of the capacitor. When the tool advances to that proximity to the workpiece that will allow the potential across the capacitor to cause ionization and disruptive breakdown of the dielectric, the condenser will discharge rapidly. Following the discharge of the capacitor, the dielectric will deionize and the condenser will charge from the source until the potential appearing across the condenser again ruptures the dielectric. This rupture potential is determined by the distance between electrode and workpiece. The high current densities that appear at the workpiece terminus of the ionized path produce resulting electrical force fields which act on the positive ions in the crystal lattice of the work. These forces result in the dislodgment of small particles of the material to be machined. Forces can be produced in excess of that required in the machining of any metal now available.

Recent Developments: Included in the many models of electrical power generating units now made are machines which utilize independently timed discharge systems, rather than the essentially relaxation machines of earlier development. In this category machines have been operated with discharge rates of up to 12,000 pulses per second, discharge currents of up to 50,000 amperes and average powers of 15 kilowatts. The acquisition of the information obtained in single discharge research was applied to the design of the cutting power generating unit, and components were selected that would provide a compromise between speed of cut and surface finish.

In electrospark machining, as in any other type machining operation, the removal of chips or displaced material that results from the machining presents a limitation to the speed with which an internal contour can be produced or a hole can be drilled. Repeated test cuts indicate that chip removal in an inside machining operation presents the greatest obstacle to increasing machining speed. Normally chip removal is accomplished by using the liquid dielectric as a vehicle. The dielectric is pumped through the area of the cut and in its passage it picks up the chips and carries them away. Even with this limitation, however, test machining using the electrospark method to produce internal shapes demonstrates rates of metal removal in sintered carbides that are multiples of the rates achieved by standard machining.

The independently timed discharge machines described above, in addition to their accelerated rate of metal removal, also utilize an energy storage system of the constant voltage type. Since the contour produced by an electrospark machine is a function of the potential that can be generated between the tool and the work, accurate control of this voltage makes it possible to repeat machining results within the limitations of the dimensional accuracy of the tool and the performance consistency of the mechanical unit which supports the tool and work.

From a paper entitled "Electrospark Machining—Metal Removal Without Contact" presented at the 18th Annual Machine Tool Electrification Forum sponsored by the Westinghouse Electric Corp., in Buffalo, N. Y., April, 1954.

Tomorrow's Production Machines

By Walter P. Hill
President
Hill Engineering Co.
Detroit, Mich.

INCREASING output per man hour lies entirely in the hands of the production engineers and machine designers. They can put into effect new processes, product redesigns and production equipment that will assure greater output and thus solidify and improve our nation's economy.

The design of production machines of the future must be aimed toward the pushbutton factory if the ultimate in lowering of product cost is to be achieved. Production machines of the future will not be standard machines; to rely on standard types of machines would be to rest on antiquity. To produce parts at maximum efficiency a machine tool must be designed for its specific operation. And further, the process in which the machine tool is used may have to be altered to attain maximum productivity. This adds up to the fact that the process must be the best, the machine must produce at a maximum rate and the part must be designed to fit the process.

One factor that is a problem in the development of new production methods and machine tools is the time required to put a facility in operation once it is built. Completely automatic machines with radical new designs require longer tryout periods than standard types. This results because of the great amount of creative effort put into machine tools engineered to produce the ultimate in production on a given job.

Tomorrow's machine tool will be a completely integrated, high speed machine which will automatically pass parts from operation to operation, gage each part at each operation and change tools when power requirements indicate the need. It will be a mass of controls, wire and hydraulic lines. It will, however, be more compact, more foolproof and require less maintenance than many dare to envision.

From a paper entitled "New Production Methods and Machine Design" presented at the 11th Annual Machine Design Conference sponsored by the Cleveland Engineering Society in Cleveland, O., February, 1954.

SUPPLEMENT

to *Machine Design's*

Directory of Materials

18th Edition—1954

Following publication of the *Directory of Materials* in May, 1954, a number of companies have supplied information on their materials. This information has been compiled for easy reference in the same general system used in the *Directory*. Tradenamed* materials and information, groupings by type of materials, and company listings are included.

Tradenames and Information

A-H5 (Tool steel)—See *Bethlehem*

AMERICAN (Gray iron, semisteel and alloyed gray iron)—American Foundries Co., 330 Second St., Milan, Mich.

ASTM A48-48, Classes 20 through 50. ASTM A159-49T, Classes 110 to 114 for semisteel and alloy gray iron. Base iron is Class 30. Castings from ounces to 15 tons. For automotive and agricultural equipment, trucks, valves, food machinery, scale equipment, machine tools, etc. Also special wear-resistant and flame-hardening irons.

AMMONODUCT (Pipe)—Bethlehem Steel Co., Bethlehem, Pa.

For refrigeration.

ArmaSTEEL (Specially heat-treated malleable iron)—Central Foundry Div., Saginaw, Mich.

ASTM A-220. For wear resistance, selective hardened parts, high yield strength. Castings for automotive rocker arms, diesel pistons, universal joint yokes, Hydra-matic transmission gears, small engine crankshafts, turbine hubs, truck trolley wheels, crankshaft sprockets.

BEARCAT (Tool steel)—see *Bethlehem*

BETHALLOY (Tool steel)—see *Bethlehem*

BETHANIZED (Electrolytically zinc-coated wire)—Bethlehem Steel Co., Bethlehem, Pa.

BETHCOLITE (Tin plate)—Bethlehem Steel Co., Bethlehem, Pa.

BETHCON (Galvanized sheets) — Bethlehem Steel Co., Bethlehem, Pa.

BETH-CO-WELD (Continuous butt-welded pipe)—Bethlehem Steel Co., Bethlehem, Pa.

BETH-CU-LOY (Copper-bearing steel sheets) —Bethlehem Steel Co., Bethlehem, Pa.

BETHLEHEM (Tool steels)—Bethlehem Steel Co., Bethlehem, Pa.

Carbon Water Hardening: Four grades (X, XCL, XX, XXX) depending upon degree of refinement in processing and amount of inspection required by customer. Carbon tool steels with carbon contents from 0.75 to 1.35, in ten point increments, available overall analysis ranges are: X—0.75 to 1.10 C, 0.03 P max, 0.035 S max; XCL—0.80 to 1.20 C, 0.02 P max, 0.02 S max; XX—0.90 to 1.30 C, 0.02 P max, 0.02 S max; XXX—0.90 to 1.35 C, 0.015 P max, 0.015 S max. Available in rounds, squares, flats, octagons, hexagons, chamfered squares and billets.

Carbon Vanadium: Similar to straight carbon tool steels in all properties and applications, these steels have an addition of approximately 0.20 V which helps to maintain grain refinement during heat treatment. Furnished in four qualities—Best, Superior, XX plus Vanadium, and XXX plus Vanadium—depending upon degree of inspection and refinement in processing necessary to insure satisfactory service. Available with various carbon contents in ten point increments within following ranges: Best—0.75 to 1.10 C, 0.03 P max, 0.03 S max, 0.20 V; Superior—0.80 to 1.35 C, 0.02 P max, 0.02 S max, 0.20 V; XX—0.90 to 1.30 C, 0.02 P max, 0.02 S max, 0.20 V; XXX—0.90 to 1.35 C, 0.015 P max, 0.015 S max, 0.20 V. Furnished in rounds, squares, octagons, hexagons, flats and billets.

BTR: 0.90 C, 1.20 Mn, 0.50 Cr, 0.50 W, 0.20 V. Oil-hardening tool steel for all general-purpose tools and dies requiring a safe-hardening steel. Easy to machine, good wear resistance, high toughness, and low distortion in heat treatment. Available in rounds, squares, octagons, hexagons, flats, billets and hollow bars.

Bethalloy: 0.75 C, 0.75 Mn, 0.90 Cr, 1.75 Ni, 0.35 Mo. Oil-hardening tool steel for general-purpose tools and dies requiring more toughness than found in higher carbon types, but with some sacrifice in wear resistance. Because of oil-hardening characteristics and consequent low distortion in heat treatment, Bethalloy can sometimes replace the silico-manganese shock tool steels where minimum dimensional change is required. Available in rounds, squares, flats and billets.

Lehigh S: 2.05 C, 11.50 Cr, 0.60 V. Oil-hardening type of high-carbon, high-chrome tool steel with highest hardness of any of the tool and die grades. Some toughness is sacrificed. Excels in wear resistance and has fine resistance to distortion during heat treatment. Available in rounds, squares, octagons, flats and billets.

A-H5: 1.00 C, 0.60 Mn, 5.25 Cr, 1.10 Mo, 0.25 V. The 5 per cent chromium air-hardening type tool steel has less distortion in heat-treatment than oil-hardening types. Available in rounds, squares, octagons, flats and billets.

Lehigh H: 1.55 C, 11.50 Cr, 0.40 V, 0.80 Mo. Standard air-hardening, high-carbon, high-chromium steel. Combines minimum size change in heat treatment with high wear resistance and fair toughness. Available in rounds, squares, octagons, flats and billets.

Omega: 0.60 C, 0.70 Mn, 1.85 Si, 0.20 V, 0.45 Mo. Shock-resisting tool steel combining great ductility and hardness. Primarily oil hardening, but very simple sections can be quenched in water. Excellent for cold battering and shock applications at normal temperatures. Avail-

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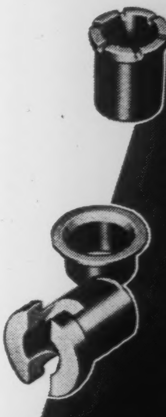

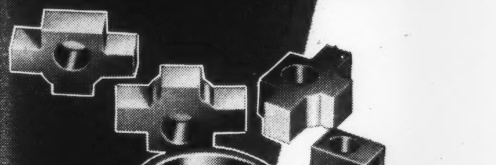

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able in rounds, squares, octagons, hexagons, flats and billets.

67 Chisel: 0.50 C, 0.75 Si, 1.15 Cr, 0.20 V, 2.50 W. General-purpose shock-resisting tool steel. Has excellent properties for cold-battering tools and hot-work applications, involving shock. Widely used for master hobs. Readily carburized where added wear resistance is needed. Available in rounds, squares, octagons, hexagons, flats and billets.

71 Alloy: 0.60 C, 2.00 Si, 0.90 Mn. Basic type of silicomanganese, shock tool steel. Develops high impact properties coupled with good balance of wear and shock resistance. An economical shock tool steel, it can be quenched in either oil or water. Furnished in the annealed condition (217 bhn), in rounds, squares, flats and billets.

Bearcat: 0.50 C, 0.70 Mn, 0.25 Si, 3.25 Cr, 1.40 Mo. Outstanding air-hardening shock tool steel. Minimum distortion in heat treatment. Great toughness, deep hardenability, good hot-work properties and machinability. Used in both hot and cold work, in punches, blanking and forming dies, rivet sets, cold riveting, master hobs. Available in rounds, squares, octagons, hexagons, flats and billets.

Lehigh L: 0.85 C, 11.50 Cr, 1.00 Ni, 0.45 Mo, 0.30 V. Low-carbon type of high-carbon, high-chromium tool steel. Low carbon content plus 1.00% nickel content gives this steel maximum toughness coupled with high abrasion resistance. Dimensional changes during heat treatment are very slight when proper practice is followed. Available in rounds, squares, flats and billets.

Cr-Mo-W: 0.35 C, 1.05 Si, 5.00 Cr, 1.65 Mo, 1.55 W. Represents the most widely used general-purpose hot-work tool steel. Excellent combination of red hardness and shock resistance. Resists both heat checking from alternate heating and cooling and drastic cooling from high temperatures. Available in rounds, squares, flats and billets.

Cr-Mo-V: 0.38 C, 1.00 Si, 5.00 Cr, 1.25 Mo, 0.45 V. Hot-work tool steel regarded as one of the outstanding developments in this field. It has an excellent combination of red hardness, toughness and abrasion resistance. Withstands drastic cooling at maximum temperatures and is sometimes preferred to the tungsten type when a minimum of heat checking and improved abrasion resistance are required. Available in rounds, squares, flats and billets.

Cr-Mo-W-V: 0.35 C, 1.05 Si, 5.15 Cr, 1.55 Mo, 1.25 W, 0.30 V. Modification of the Cr-Mo-W grade having vanadium added. Used for large extrusion press parts and dies in the nonferrous metals industry. Available in rounds, squares, flats and billets.

Cr-Mo-V (High Vanadium): 0.38 C, 5.25 Cr, 1.25 Mo, 1.05 V, 1.00 Si. Hot-work tool steel for intermediate to long service life for medium-temperature die casting. Has high resistance to abrasion and heat checking. Furnished in the annealed condition (217 bhn), in rounds, squares, flats and billets.

57 HW: 0.35 C, 3.25 Cr, 9.35 W, 0.30 V. The 9.00 per cent tungsten-type of hot-work tool steel. Excellent red hardness and abrasion resistance with good shock resistance at high operating temperatures. Cannot be drastically liquid cooled in operation. Available in rounds, squares, flats and billets.

57 Special: 0.42 C, 0.30 V, 14.00 W, 3.50 Cr. Properties much the same as 57 HW but higher tungsten content results in increased ability to retain hardness at high temperatures with improved wear resisttance. Replaces 9.00 per cent tungsten grade where increased red hardness and wear resistance at some sacrifice in toughness are required. Cannot be drastically liquid cooled in operation. Available in rounds, squares, flats and billets.

HW8: 0.60 C, 3.60 Cr, 8.50 Mo, 1.75 V. A higher carbon, highly alloyed hot-work tool steel. Outstanding steel for applications involving high surface wear, with adequate toughness and resistance to heat checking. Available in rounds, squares, flats and billets.

Special HS: 0.73 C, 18.00 W, 4.00 Cr, 1.10 V. Best known composition for high-speed steel of the 18-4-1 analysis. General-purpose grade for cutting tool operations where high red hardness, wear resistance and toughness are required. Available in rounds, octagons, squares, flats and billets.

66 HS: 0.83 C, 5.00 Mo, 4.15 Cr, 1.90 V, 6.35 W. High-speed steel of the 6-5-4-2 composition. Relatively high carbon content and balanced analysis give properties applicable to all general-purpose high-speed applications. Available in rounds, squares, octagons and flats.

HMHS: 0.78 C, 8.50 Mo, 3.85 Cr, 1.60 W, 1.05 V. High-molybdenum, low-tungsten type of tool steel. Suitable for all general-purpose cutting tools except those involving heavy-duty, continuous cutting operations where maximum red hardness is essential.

M-10: 0.87 C, 8.35 Mo, 4.00 Cr, 2.05 V. High-molybdenum type of high-speed steel with no tungsten addition. When processed under careful controls and heat treated in modern equipment, M-10 gives service comparable to other types of high-speed steels. Has proved highly satisfactory for twist drills, reamers and other single and multiple-point cutting tools. Available in rounds, squares, octagons and flats.

Comokut: 0.73 C, 18.25 W, 4.50 Cr, 1.25 V, 5.00 Co, 0.75 Mo. High-speed tool steel of the 18-4-1 composition with 5.0% cobalt for added red hardness without reduction in toughness. Particularly well suited for tools involving heavy hogging cuts where high cutting-edge pressures and temperatures are developed. Processed similarly to 18-4-1. Available in rounds, squares, octagons, flats and billets.

Red Sabre: 1.50 C, 4.75 Cr, 5.00 Co, 12.50 W, 5.00 V. A super high-speed steel, extremely abrasion resistant and considerably harder than standard high-speed steels. Suitable for a full range of cutting operations from fine finishing to heavy hogging cuts. Available in hardened and finish-ground tool bits only.

Duramold A: 0.07 C, 0.40 Mn, 0.25 Si, 4.50 Cr, 0.45 Mo. Air-hardening hobbing die steel. Annealed to 109 bhn max. Alloy content improves core strength and helps to produce a mirror-like finish in the cavity. Low distortion in heat treatment, high surface hardness and excellent core strength. Available in rounds and billets.

Duramold B: 0.06 C, 0.30 Mn, 0.20 Si, 2.0 Cr, with boron added. Oil-hardening. Annealed to 100 bhn max. Outstanding cold-hobbing plastic-molding die steel. Available in rounds, squares, flats, billets.

Duramold C: 0.06 C, 0.15 Mn, 0.10 Si. Water-hardening, cold-hobbing die steel. Annealed to 90 bhn max. Available in rounds, squares, flats and billets.

Duramold N: 0.10 C, 0.40 Mn, 1.50 Cr, 3.25 Ni, 0.25 Si. Case hardening, plastic molding die steel. Has exceptional core strength and develops a deep carburized case in sections up to 5 in. thick. Used for large-cavity dies where high mold pressures are generated, for long-run applications, where the plastic is abrasive in character. Cavities are generally produced by machining. Available in rounds, squares and billets.

Brake Die: 0.51 C, 0.95 Cr, 0.87 Mn, 0.20 Mo. This special-purpose tool steel was developed expressly for use in dies for hand and mechanically-operated press brakes, for forming flat-rolled metallic and nonmetallic materials. Shipped in heat-treated condition, stress relieved and straightened, ready for machining. Machines to a smooth finish without grinding. Because it is stress-relieved, warpage during machining is held to a minimum. Available in squares and flats.

Non-Tempering: 0.35 C, 0.70 Mn, 0.45 Si, 0.80 Cr, 0.25 Mo, 0.30 Cu. For general-purpose tools requiring shock resistance with moderate hardness at normal temperatures. Can be quenched in water or oil, from a rather wide range of temperatures. Has a satisfactory combination of hardness and toughness in the as-quenched condition, so that no tempering is required. Available in rounds, squares, octagons, hexagons, flats and billets.

BRAKE DIE (Tool steel)—see *Bethlehem*

BTR (Tool steel)—see *Bethlehem*

CHATEAUGAY (Low-phosphorus, copper-free pig iron)—Republic Steel Corp., Republic Bldg., Cleveland 1, O.

67 CHISEL (Tool steel)—see *Bethlehem*

COMOKUT (Tool steel)—see *Bethlehem*

CUTNO (Nonmetallic packing)—see *Palmetto*

DOW CORNING (Silicone adhesives, abhesives, defoamers, greases, release agents, resins, varnishes, rubber)—Dow Corning Corp., Midland, Michigan

Adhesives: C-269 and C-271. Pressure-sensitive mass for tape or cloth. Excellent adhesion to most metal, plastic or glass surfaces. Applicable at temperatures from —67 to 500 F; durably adhesive after long exposure to such temperatures.

Abhesives: 1107. Sizing for paper and parchment which prevents adhesion of most sticky materials. Treated paper is used to interleave industrial or food products, package sticky materials.

Defoamers: Antifoam A. Kills foam in the batch or continuous processing of a wide variety of aqueous and nonaqueous systems; in steam distilling; and in vacuum concentrating. Generally effective at concentrations in the range of 1 to 200 parts per million, it reduces or eliminates danger of product contamination. Physiologically harmless, its use in food processing is permissible at concentrations up to 10 parts per million. Also available in the form of a water dispersible emulsion containing 30 percent Antifoam A.

Greases: 44 grease is a heat-stable ball bear-bearing grease serviceable from —40 to 400 F. Has over ten times the life of organic greases at high temperatures; makes possible permanent lubrication at normal temperatures. 33 grease is serviceable from —100 to 350 F. 41 grease is serviceable from —20 to 450 F and upward; used in conveyor bearings, oven machinery, and compressor valves. Also an effective antiseize for hold-down bolts, injection-mold nozzles and similar threaded parts on high-temperature equipment.

Release Agents: Dow Corning Mold Release Fluid, Dow Corning 20, 35B emulsion, 7 compound, and 7 emulsion are used effectively in various release applications in rubber, plastics, plywood, and metal-fabricating industries. Inert, heat-stable and noncarbonizing, these silicones provide a clean easy break between mold surface and parts fabricated, reduce scrap and minimize mold cleaning. Dow Corning 8 emulsion F-452 and F-496 fluid are emulsion type and solvent type parting agents, respectively, for the shell process of casting metals. Give positive release at minimum cost, improve surface finish of resin sand shells, and minimize pattern cleaning.

Resins: Dow Corning 802, 803, 804, 805, 806 and 840 are a series of silicone resin vehicles for high-temperature paints and enamels. Protective finishes formulated with these resins withstand long exposure to temperatures of 500 to 100 F. They show excellent gloss retention, freedom from chalking, exceptional resistance to moisture, oxidation and attack by chemical fumes. Modified silicone resins, including both air drying and baking types, are available for formulating protective coatings or for cold blending with organic paint vehicles to reduce chalking and to improve moisture resistance as well as gloss and color retention. Dow Corning R-543 and R-544 resin produce rigid, nonflammable, heat-stable, low density, foam structures for fire walls; thermal, electrical and acoustical insulation. Dow Corning 2103, 2104, 2105 and 2106 are bonding resins for making glass cloth laminates; 2103 and 2105 are primarily electrical insulating materials; 2104 and 2106 are low pressure laminating resins. Laminates made with various types glass cloth, bonded with these resins, possess characteristic properties which make them adaptable to a variety of applications including electrical and structural components.

Varnishes: Dow Corning 935 and 994 varnish are cloth coating materials for producing Class H electrical insulating components. Dow Corning 996 and 997 are heat-stable, dielectric, impregnating varnishes for Class H electrical and electronic equipment.

Rubber: Silastic, the Dow Corning silicone rubber, produced in over 70 different stocks and pastes; used to fabricate resilient gaskets, diaphragms, seals, and ducts which are resistant to heat, oxidation, weathering, and are serviceable over an unusually wide range of temperatures. Silastic has high thermal conductivity, excellent resistance to corona, and good physical and dielectric properties that remain relatively constant over a wide range of temperatures and frequencies. RTV Silastic cures at room temperature, provides new working form of these resilient

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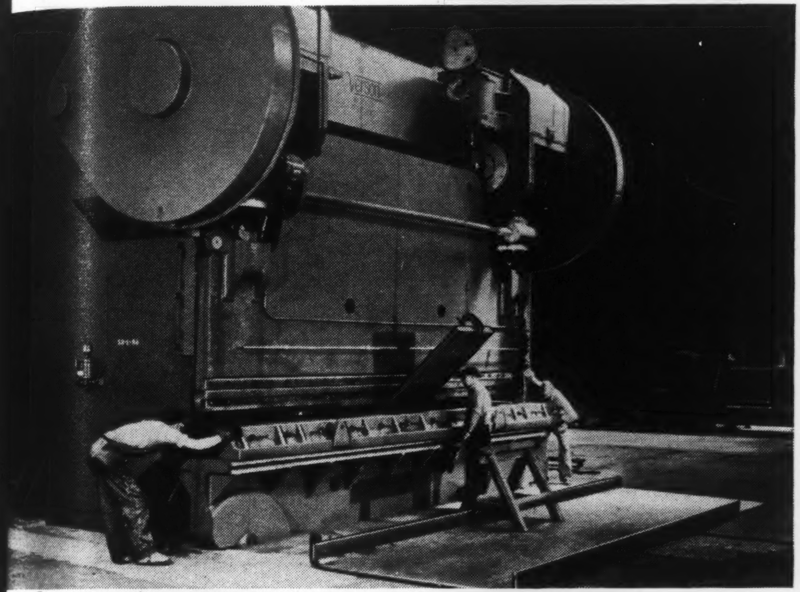

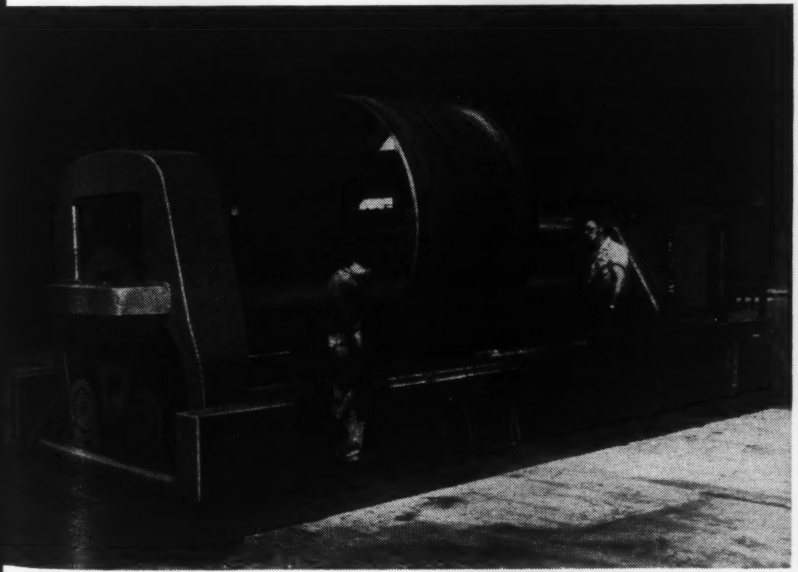

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materials; is adaptable to those applications where high curing temperatures cannot be attained or tolerated.

DURAMOLD (Tool steel)—see *Bethlehem*

EBONOL (Black oxide coatings) — Enthone Inc., 442 Elm St., New Haven 11, Conn. C for copper; Z and Z-80 for zinc; S and S-30 for ferrous metals.

ELECTRO PAINTLOK (Electrogalvanized, chemically treated sheets)—Republic Steel Corp., Republic Bldg., Cleveland 1, O.

ENDURO (Stainless steel)—see *Republic Enduro*

ENTHONE COMPOUND 39 (Phosphate coating)—Enthone Inc., 442 Elm St., New Haven 11, Conn.

ENTHOX (Chromate conversion coating)—Enthone Inc., 442 Elm St., New Haven 11, Conn.

FORM-SET (Preformed wire rope)—Bethlehem Steel Co., Bethlehem, Pa.

GRC (Small zinc-alloy die castings)—Gries Reproducer Corp., 32 Second St., New Rochelle, N. Y.

Small zinc alloy die castings up to ½-oz.

GRIES (Small zinc-alloy die castings)—Gries Reproducer Corp., 32 Second St., New Rochelle, N. Y.

Small zinc alloy die castings up to ½-oz.

HITCHINER (Precision investment castings)—Hitchiner Mfg. Co. Inc., Milford, N. H.

Investment cast ferrous and nonferrous alloys. Cast steel (carbon and alloy), cast high alloys and stainless steels. Aluminum, copper, magnesium and nickel base. Precious metals.

HMHS (Tool steel)—see *Bethlehem*

66 HS (Tool steel)—see *Bethlehem*

HW8 (Tool steel)—see *Bethlehem*

57 HW (Tool steel)—see *Bethlehem*

INTERCAST (Small zinc-alloy die castings)—Gries Reproducer Corp., 32 Second St., New Rochelle, N. Y.

Small zinc alloy movable-element die castings produced assembled in one operation; up to ½-oz.

KLERO (Noncontaminating packing) — see *Palmetto*

LEHIGH (Tool steels)—see *Bethlehem*

M-10 (Tool steel)—see *Bethlehem*

MAYARI (Bolt steel)—Bethlehem Steel Co., Bethlehem, Pa.

For engine bolts and staybolts.

MAYARI R (Low-alloy, high strength steel)—Bethlehem Steel Co., Bethlehem, Pa.

High resistance to atmospheric corrosion, abrasion and impact.

MILANITE (Machinable alloy cast iron)—American Foundries Co., 330 Second St., Milan, Mich.

Readily machinable alloy cast iron with ts (specimens from ⅞-in. diam cast bars), 40,000 psi; hardness, 179-207 bhn.

MYLAR (Polyester plastic film)—E. I. du Pont de Nemours & Co. Inc., Film Dept., Wilmington 98, Del.

Durable, water-repellent and chemically resistant film having high dielectric resistant film having high dielectric strength. High tensile and impact strength. Remains flexible and stable from −60 to 150 C. Applications include dielectric in capacitors, tape insulation for motors and generators, magnet wire insulation, transformer-coil insulation, magnetic recording tape base, linings, pipe wrapping, laminated materials, etc. Available in three types as follows:

A. Low fault-count (measure of pinholes or spots of dielectric weakness) for general use as insulation and dielectric material. Thin gages (25, 50, 100) have good transparency; heavier gages (500, 750) are translucent. Rolls and cut-to-size sheets.

C. Low fault count and good high-temperature and insulation resistance. Primarily for use as dielectric in high-temperature capacitors. Rolls only.

D. Highly transparent film in heavy gages. Rolls only.

NEILLITE (Phenolic plastic molding compound)—Watertown Mfg. Co., Watertown, Conn.

Phenol-formaldehyde molding powder. For electrical switches, control handles, terminal blocks, panels, etc.

NON-TEMPERING (Tool steel)—see *Bethlehem*

OMEGA (Tool steel)—see *Bethlehem*

PAGE & HALL (Short-run zinc die castings)—Page & Hall Mfg. Co. Inc., 1600 Hyde Park Ave., Boston 36, Mass.

Short-run die castings of Zamak alloys 3 and 5

PAINTGRIP (Cold-rolled steel)—Armco Steel Corp., 703 Curtiss St., Middletown, O.

Steel sheets or strip flashed with zinc and mill-treated for immediate painting.

PALCO (Plaited cotton packing)—see *Palmetto*

PALMETTO (Packings and gaskets)—Greene, Tweed & Co., North Wales, Pa.

NONMETALLIC PACKINGS as follows:

Braided No. 1000: general service on air, steam and water.

Twist No. 1010: valve stems, small shafts and rods on air, steam, water.

Plaited No. 1030: centrifugal pumps on air, steam, water.

Pelro No. 1100: oil, gasoline and solvent service.

Cutno No. 1200: alkali and caustic soda service.

Super Cutno No. 1300: acid-handling pumps and valves.

Teflon No. 1330: braided Teflon-impregnated blue asbestos for highly corrosive fluids or solvents on valves and slow-rotating shafts.

Teflon No. 1335: plaited, soft-construction, Teflon-impregnated blue asbestos for highly corrosive fluids or solvents on valves and slow-rotating shafts.

Teflon No. 1335: plaited, soft-construction, Teflon-impregnated blue asbestos for centrifugal pumps.

Klero No. 1400: plaited for noncontaminating pump service handling foodstuffs, milk, beer, soft drinks, etc.

Flax No. 1600: plaited long-line flax for general cold water, oil hydraulics and marine services.

Palco No. 1800: plaited cotton packing for water service, sewage, slurry and sludge pumps.

SHEET PACKINGS as follows:

Supersheet No. 2900: compressed asbestos for general service on flanges. Exceeds MIL-A-7472, 33-P-13 and HH-P-46 specifications.

No. 2910: compressed asbestos for oil, gasoline, petroleum-solvent and alkali services. AMS-3232 F.

No. 2915: compressed asbestos for aeronautical use in fuel, lubricant, coolant and temperature-resistant applications. MIL-G-7021, Class 1 (formerly AN-G-171, Class 1).

No. 2970: blue compressed asbestos for most acids in dilute and concentrated forms.

No. 2930: high-grade red rubber for flange and joint packing in low-pressure and other general services.

No. 2960: Vegetable fiber for petroleum, oil, gas at normal temperatures and pressures, and for automotive gaskets. MIL-P-20085.

RUBBER-MOLDED SEALS: V-packings, cups, V-rings and flange packings, molded in fabric and rubber (or synthetic) compositions. Palmetto G-T ring packing, O-rings, molded-rubber gaskets and other special-design precision-molded seals.

PELRO (Nonmetallic packing)—see *Palmetto*

PENNROLD (Beryllium copper)—Penn Precision Products Inc., 501 Crescent Ave., Reading, Pa.

10: 0.5 Be, 2.5 Co, bal. Cu. High electrical and thermal conductivity, good strength and hardness, nonmagnetic, excellent resistance to corrosion, fatigue and wear. Strip (0.001 to 0.040-in.) available heat treatable or heat treated. For contacts, springs, switch parts, etc.

25: 1.9 Be, 0.3 Co, bal Cu. ASTM B194; AMS 4530, 4532; MIL-C-947, MIL-C-6942, Federal QQ-C-533. High strength and hardness, good electrical and thermal conductivity, nonmagnetic, excellent resistance to corrosion, fatigue and wear. Strip (0.001 to 0.040-in.) available in heat treatable condition. For springs, bellows, diaphragms, contacts, instrument parts, connectors, terminals, etc.

PENNROLD PRECISION STRIP (Copper alloys)—Penn Precision Products Inc., 501 Crescent Ave., Reading, Pa.

Copper, brass, phosphor bronze, nickel silver, beryllium copper, etc. Available as thin-gage, close-tolerance strip in thicknesses from 0.001 to 0.032-in. and widths from $\frac{3}{32}$ to 6 in. For springs, contacts, shims, terminals, diaphragms, precision instruments and electronics parts, etc.

PENNTEMP (Beryllium copper)—Penn Precision Products Inc., 501 Crescent Ave., Reading, Pa.

165: 1.7 Be, 0.3 Co, bal Cu. Mill-hardened strip offering excellent strength, hardness, conductivity and corrosion resistance. Available in strip form (0.001 to 0.025-in.) requiring no heat treatment. For springs, contacts, connectors, terminals, electronics parts, etc.

PURE (Carbon products)—Pure Carbon Co. Inc., St. Marys, Pa.

Carbon, graphite, metal-graphite and metallic brushes; slip-ring brushes; special carbon forms and products; carbon electrodes for welding; contacts (electric circuit, contactors, ignition points, etc.); carbon and graphite molds; carbon and graphite plates in all grades and thicknesses for motor and generator brushes.

PUREBON (Carbon products)—Pure Carbon Co. Inc., St. Marys, Pa.

Graphite bearings; self-lubricating (carbon) and aircraft (carbon) bearings; ring packing (carbon for turbine packing rings, thrust bearings, etc.); sealing rings; carbon seals; oil, grease and dust seals.

PUREMET (Powdered metal products)—Pure Carbon Co. Inc., St. Marys, Pa.

Powdered metal parts; oilless or self-lubricating bearings; thrust, oil-bath type bearings.

PURPLE STRAND (Wire rope)—Bethlehem Steel Co., Bethlehem, Pa.

PYRON (Flame-hardenable alloy gray iron)—American Foundries Co., 330 Second St., Milan, Mich.

Alloy gray cast iron specifically for flame or induction hardening. Can be machined to finish-grind dimension, then flame hardened. Hardness, as cast, 200-250 bhn (300 kg load, 10-mm ball). Optimum hardness, 50 Rock C. For gears, cams, sprockets, rollers, plungers, sheaves, machine-tool ways, dies, etc.

RAYDUCT (Pipe)—Bethlehem Steel Co., Bethlehem, Pa.

For radiant heating and fabricating purposes.

RED SABRE (Tool steel)—see *Bethlehem*

REPUBLIC (Alloy steels) — Republic Steel Corp., Alloy Steel Div., Massillon, O.

REPUBLIC (Steels) — Republic Steel Corp., Republic Bldg., Cleveland 1, O.

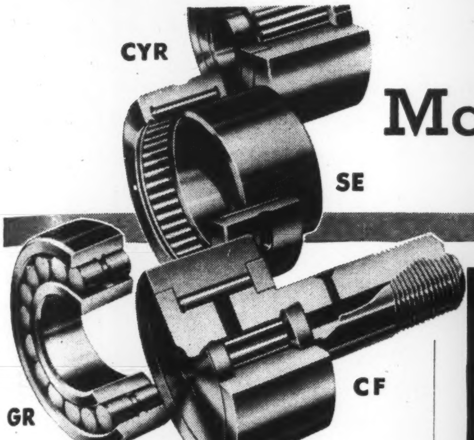
Carbon, alloy and stainless steels. Semi-finished, hot-rolled and cold-drawn bars, sheets, strip, wire; pig iron; tin plate; pipe. Electrical sheets and coiled silicon strip. Copper steel. High-strength steels. Toncan copper-molybdenum iron. Galvannealed sheets. Electro Paintlok sheets. Electro Zincbond sheets. Powder metals.

REPUBLIC (Titanium)—Republic Steel Corp., Alloy Steel Div., Massillon, O.

RS-55: Commercially pure titanium. Min ys, 55,000 psi. Min ts, 65,000 psi. Min elong, 20%. High-ductility grade produced in sheet, plate, bar, billet and wire forms. Normal annealed structure is equiaxed alpha. Shows no response to heat treatment.

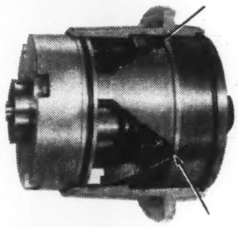
RS-70: Commercially pure titanium. Min ys, 70,000 psi. Min ts, 80,000 psi. Min elong, 18%. Produced in sheet, plate, bar, billet and wire. Normal annealed structure equiaxed alpha. Shows no response to heat treatment.

RS-70-A: Similar to RS-70 except 1.25 max



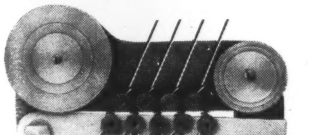
McGILL BEARING BRIEFS

MULTIROL CF BEARINGS PROVIDE POSITIVE CAM ACTION IN ANCHOR CUT-OUT

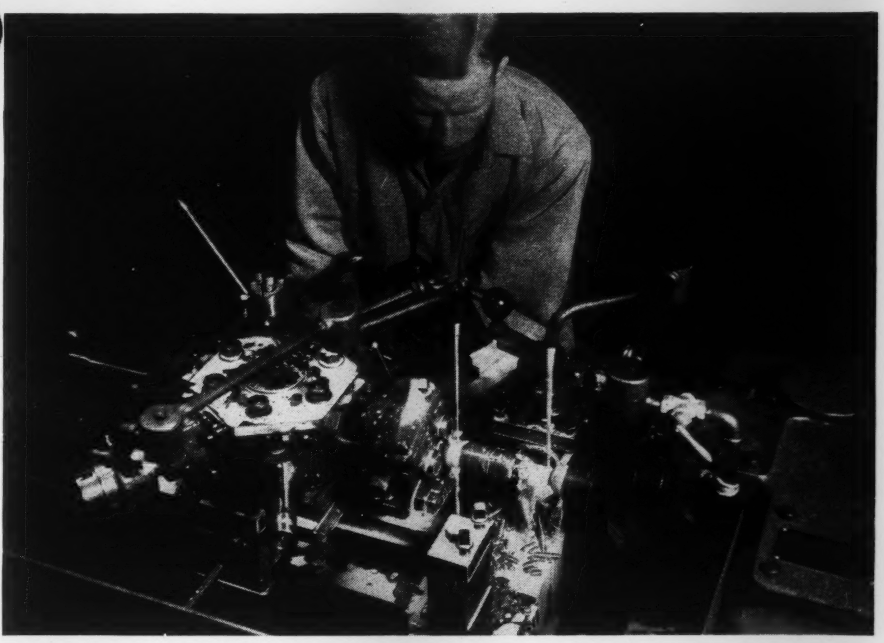


Anchor Steel and Conveyor Company relies on Multirol Cam Follower Bearings for positive and instant operation of Anchor cut-out couplings. When dangerous overload occurs this torque sensitive coupling cuts power when a spring loaded sliding sleeve is actuated by forcing CF series bearings up the inclined faces of a circular cam. Shock load capacity and dependability of CF series bearings combine to help the Anchor Company protect motors and machinery from damage due to overload.

SJOGREN KILLERS CAST WIRE ON MULTIROL CF BEARINGS

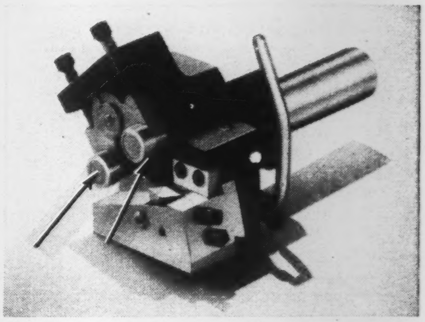


On Sjogren Killers for casting wire, Multirol CF bearings with outer races grooved to required wire size have replaced hardened steel rollers. Sjogren maintained required accuracy at much higher casting speeds with minimum of grease instead of objectionable oil lubrication.



Warner & Swasey Uses MULTIROL® *CF Bearings as*

STEADY REST ROLLERS ON TURRET LATHES

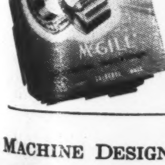


The precision turning done on Warner & Swasey Turret Lathes depends to a great extent on providing adequate, accurate and free turning support for the work in process. The pressure of the cutting tool must be backed up on the end opposite the chuck so that depth of cut and concentricity remains constant.

This support is provided with tool holders using two Multirol Cam Follower bearings as steady rest or bar turning rollers. The precision quality of these rolls is very important to efficient operation. Free turning rolls of adequate capacity will assure work with a smooth finish and a high degree of accuracy.

Warner & Swasey have been using Multirol CF Series bearings in this application for over 15 years. They adopted the McGill bearing after finding its precision quality, resulting from close radial tolerances, ideal to help insure superior lathe performance.

The outer ring of Multirol CF Bearings operates on a full complement of small diameter rollers so the load is evenly distributed over a greater bearing surface. The inner race and flange are made in a single piece with the stud, preventing any possibility of disassembly. Close tolerance grinding of all bearing surfaces insures greater accuracy throughout longer bearing life and, compared with plain bearings, lubrication is simplified and less critical. Both starting and rolling friction are reduced to a minimum. As a result, internal wear is diminished and power requirements of Multirol bearing equipped machines are cut appreciably.



BEARING SELECTION GUIDE
A new 140-page Bearing Selection Guide, complete with 30 pages of vital engineering data, has been released by the McGill Manufacturing Co. Ask for Catalog No. 52.

McGILL® — Precision Bearings
McGILL MANUFACTURING COMPANY, INC.
200 N. Lafayette Street, Valparaiso, Indiana

Mn is added during melting. Mn may enhance formability at 70,000 psi yield range without sacrificing other characteristics of RS-70.

RS-110: Bar and forging alloy containing about 3.5 Cr and 1.5 Fe with low residuals of O and N. Min ys, 110,000 psi. Min ts, 120,000 psi. Min elong, 12%.

RS-110-A: High-strength, ductile alloy contains nominal 7 Mn; primarily a sheet alloy. Normal annealed structure equiaxed alpha and beta grains. Heat treatable. Min ys, 110,000 psi. Min ts, 120,000 psi. Min elong, 10%.

RS-130: High-strength bar and forging alloy with nominal composition of 4 Mn and 4 Al. Normal microstructure equal amounts of alpha and beta phases. Min ys, 130,000 psi. Min ts, 140,000 psi. Min elong, 10%.

REPUBLIC DOUBLE STRENGTH (High-strength steel)—Republic Steel Corp., Republic Bldg., Cleveland 1, O.

REPUBLIC ENDURO (Stainless steel)—Republic Steel Corp., Alloy Steel Div., Massillon, O.

Also stainless clad sheets

SABECO (Bearing bronzes)—Saginaw Bearing Co., 821 S. Water St., Saginaw, Mich.

High-lead bearing bronzes, available as bar stock, castings and finished machined parts. Compositions and applications as follows:

No. 5: 69-71 Cu, 4.5-5.5 Sn, 24-26 Pb, 0.2 max impurities. For light or medium-load and water-lubricated bearings.

No. 7: For connecting rods in refrigerating compressors and gasoline engines.

No. 9: 69-71 Cu, 8.5-9.5 Sn, 20-22 Pb, 0.2 max impurities. For heavy loads such as average machine-tool requirements.

No. 11: 69-71 Cu, 10.5-11.5 Sn, 18-20 Pb, 0.2 max impurities. For worm wheels, clutch shifter shoes, forging machine slides, and extreme heavy bearing conditions.

No. 16: 69-71 Cu, 15-16.5 Sn, 13.5-14.5 Pb, 0.2 max impurities. For friction rings, and heavy-duty boring spindle bearings.

SILASTIC (Silicone rubber)—see *Dow Corning*

SILVER STAR (Spring wire) — Bethlehem Steel Co., Bethlehem, Pa.

57 SPECIAL (Tool steel)—see *Bethlehem*

SPECIAL HS (Tool steel)—see *Bethlehem*

SUPERSHEAT (Compressed-asbestos sheet packing)—see *Palmetto*

TONCAN (Rust-resisting copper-molybdenum iron) — Republic Steel Corp., Republic Bldg., Cleveland 1, O.

TRAN-COR (Electrical steels)—Armco Steel Corp., 703 Curtiss St., Middletown, O.

T. Insulated iron-silicon alloy. High permeability; low hysteresis loss; high lamination factor; minimum interlamination energy loss; unoriented. Coils up to 12⅜ in. wide weighing approximately 1000 lb; 0.005 and 0.007-in. thick. Magnetic amplifier cores, plate and filament transformer laminations are typical uses.

Oriented T. Insulated iron-silicon alloy. High permeability oriented in direction of rolling; low hysteresis loss; high lamination factor; minimum interlamination losses. Coils up to 12⅜ in. wide; 0.004-in. thick coils weigh approximately 1000 lb; 0.002-in. thick coils weigh approximately 500 lb; 0.001-in. thick coils weigh approximately 300 lb. No strip less than 100 ft long. Magnetic amplifier cores, pulse transformer laminations are typical uses.

Oriented T-S. Insulated iron-silicon alloy. Extra-high permeability in rolling direction; low hysteresis loss; high lamination factor; minimum interlamination energy loss. Coils up to 12⅜ in. wide; no strip less than 100 feet; 0.004-in. thick coils weigh approximately 300 lb. High cycle motor laminations, magnetic amplifier cores are typical applications.

UNION (Cold-drawn steels)—Republic Steel Corp., Union Drawn Steel Div., Massillon, O.

Also see *Republic*

WALLINGFORD (Steel tubing, pipe and strip) —Wallingford Steel Co., Wallingford, Conn.

Stainless-steel tubes and pipe; stainless and carbon steel cold-rolled strip; extruded shapes. Standard analyses include AISI 302, 304 ELC, 309, 310, 316 ELC, 316 Cb, 317, 321, 347 and 430. Special steels available.

Index by Type of Material

Ferrous Metals

CAST FERROUS METALS

Cast Iron, Carbon and Alloy (Gray Iron and Semisteel)

Gray iron, semisteel and alloyed gray iron—AMERICAN
Machinable alloy cast iron—MILANITE
Flame-hardenable alloy gray iron—PYRON

Malleable Iron

Specially heat-treated malleable iron—ArmaSTEEL

Cast Steel, Carbon and Alloy

Precision investment castings—HITCHINER

Cast High Alloys

Precision investment castings—HITCHINER

Other Cast Ferrous Metals

Precision investment castings—HITCHINER

CLAD METALS

Stainless clad sheets—REPUBLIC ENDURO

POWDER METALS

Powdered metal products—PUREMET
Powder metals—REPUBLIC

STEEL, PREFINISHED OR PREPLATED

Electrolytically zinc-coated wire—BETHANIZED
Tin plate—BETHCOLITE
Galvanized sheets—BETHCON
Zinc-plated (electrolytic), chemically treated sheets—ELECTRO PAINTLOK
Cold-rolled steel—PAINTGRIP

STEEL, STAINLESS (Wrought)

Stainless steels—REPUBLIC ENDURO
Steel tubing, pipe and strip—WALLINGFORD

STEEL, TOOL AND DIE

Tool steels—BETHLEHEM

STEEL, WROUGHT CARBON

Refrigeration pipe—AMMONODUCT
Spring wire—SILVER STAR
Continuous butt-welded pipe—BETH-CO-WELD
Preformed wire rope—FORM-SET
Cold-rolled steel—PAINTGRIP
Wire rope—PURPLE STRAND
Pipe—RAYDUCT
Cold-drawn steels—UNION
Steel tubing, pipe and strip—WALLINGFORD

STEEL, WROUGHT ALLOY

Chromium Steel

Alloy steels—REPUBLIC

Chromium-Manganese Steel

Alloy steels—REPUBLIC

Chromium-Molybdenum Steel

Alloy steels—REPUBLIC

Chromium-Vanadium Steel

Alloy steels—REPUBLIC

Low Alloy Steel

Low alloy, high strength steel—MAYARI R
High-strength steel—REPUBLIC DOUBLE STRENGTH

Manganese Steel

Alloy steels—REPUBLIC

Molybdenum Steel

Alloy steels—REPUBLIC

Nickel Steel

Alloy steels—REPUBLIC

Nickel-Chromium Steel

Alloy steels—REPUBLIC

Nickel-Chromium-Molybdenum Steel

Alloy steels—REPUBLIC

Nickel-Molybdenum Steel

Alloy steels--REPUBLIC

Other Alloy Steels (not otherwise classified)

Copper-bearing steel sheets—BETH-CU-LOY
Bolt steel—MAYARI
Silicon sheets and coiled silicon strip (electrical)—REPUBLIC
Electrical steels—TRAN-COR

Nonferrous Metals

ALUMINUM BASE

Cast Aluminum

Precision investment castings—HITCHINER

COPPER BASE

High Copper

Beryllium copper—PENNROLD
Copper alloys—PENNROLD PRECISION STRIP
Beryllium copper—PENNTEMP

Copper-Aluminum

Precision investment castings—HITCHINER

Copper-Lead

Bearing bronzes—SABECO

Copper-Silicon

Precision investment castings—HITCHINER

Copper-Tin (Bronze)

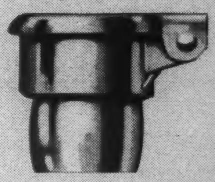
Precision investment castings—HITCHINER
Copper alloys—PENNROLD PRECISION STRIP

Here's How

GITS

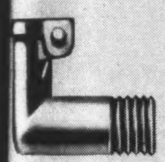
Helps Give

Built-In Low Cost To YOUR Equipment



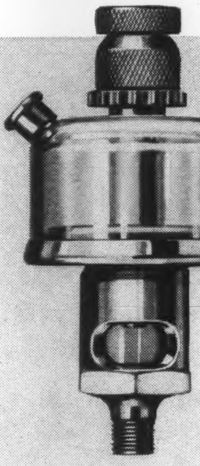
OIL HOLE COVERS

This model is designed to fit into a simple drilled hole. Ideal for use on small motors, generators, starters and light machinery—for dependable oil hole protection at moderate cost. Larger sizes frequently used as filler caps on tanks or reservoirs. Style R—No. 305.



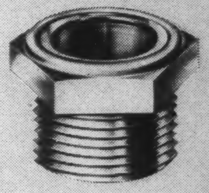
OIL CUPS

ccurately machined from a lid brass one-piece forging, s oil cup permits safe, dendable application of lubrint at very low cost. Used dely on motors and small mainery requiring side oiling. yle L—No. 1202.



SIGHT GRAVITY FEED OILERS

Rate of oil flow regulated by needle valve, directly observed through sight glass in stem. Shut-off knob does not affect needle valve adjustment. Visible oil supply. Non-breakable. Tops in convenience and dependability, at low cost. Style NFU—No. 3602-A.

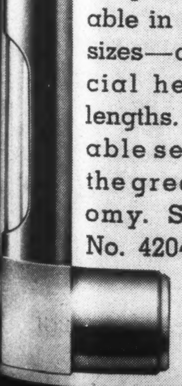


GEAR CASE GAUGES

This oil gauge plug permits instant checking of oil level within a transmission or gear case. For use where construction permits insertion in tapped hole. A valuable addition to any such equipment — at very low cost. Style BW—No. 4042.

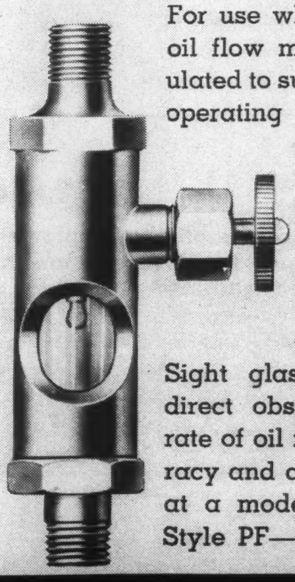
ORGED BRASS GAUGES

eavily constructed in a single ece from forged brass — this gauge is also drilled to permit generous oil passage. Available in many stock sizes—and in special heights and lengths. For dependable service with the greatest economy. Style FG—No. 4204.



SIGHT GAUGES

For use where rate of oil flow must be regulated to suit changing operating conditions. Needle valve permits extremely accurate adjustment of oil feed. Sight glass provides direct observation of rate of oil flow. Accuracy and convenience at a moderate price. Style PF—No. 4290.



Don't price yourself out of the mar ket. When you design proper lubri cation into your equipment, specify GITS Lubricating Devices—the wid est selection available anywhere The items pictured above are only c few of our many thousands of lubri cating devices. At the design stage, get the GITS story. Free Engineering Service. Send NOW for your free Catalog.

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Chicago 23, Illinois

Clip this page for handy "rough reference"

Copper-Zinc (Brass)
Precision investment castings—HITCHINER

Copper-Zinc-Nickel
(also Copper-Nickel-Zinc)
Precision investment castings—HITCHINER
Copperalloys—PENNROLD PRECISION STRIP

Copper-Zinc-Tin
Precision investment castings—HITCHINER

MAGNESIUM BASE
Precision investment castings—HITCHINER

NICKEL BASE
Precision investment castings—HITCHINER

POWDER METALS
Powdered metal products—PUREMET

PRECIOUS METALS
Precision investment castings—HITCHINER

TITANIUM BASE
Titanium—REPUBLIC

ZINC BASE
Small zinc-alloy die castings—GRC
Small zinc-alloy die castings—GRIES
Small zinc-alloy die castings—INTERCAST
Short-run zinc die castings—PAGE & HALL

Nonmetallic Materials

ADHESIVES AND SEALERS
Silicone adhesives, abhesives, defoamers, greases, release agents, resins, varnishes, rubber—DOW CORNING

CARBON AND GRAPHITE
Carbon products—PURE
Carbon products—PUREBON

PLASTICS—THERMOSETTING
Phenolic
Phenolic plastic molding compound—NEIL-LITE

Polyester and Allyl
Polyester plastic film—MYLAR

Silicone
Silicone adhesives, abhesives, defoamers, greases, release agents, resins, varnishes, rubber—DOW CORNING

RUBBER
Silicone adhesives, abhesives, defoamers, greases, release agents, resins, varnishes, rubber—DOW CORNING

Finishes and Coatings

CHEMICAL CONVERSION COATINGS
Phosphate coating—ENTHONE COMPOUND 39
Chromate conversion coating—ENTHOX

ENAMELS
Silicone adhesives, abhesives, defoamers, greases, release agents, resins, varnishes, rubber—DOW CORNING

OXIDE COATINGS
Black oxide coatings—EBONOL

HIGH-TEMPERATURE COATINGS
Silicone adhesives, abhesives, defoamers, greases, release agents, resins, varnishes, rubber—DOW CORNING

VARNISHES
Silicone adhesives, abhesives, defoamers, greases, release agents, resins, varnishes, rubber—DOW CORNING

Materials Producers

American Foundries Co., 330 Second St., Milan, Mich.
Gray iron, semisteel and alloyed gray iron—AMERICAN
Machinable alloy cast iron—MILANITE
Flame-hardenable alloy gray iron—PYRON

Armco Steel Corp., 703 Curtiss St., Middletown, O.
Cold-rolled steel—PAINTGRIP
Electrical steels—TRAN-COR

Bethlehem Steel Co., Bethlehem, Pa.
Refrigeration pipe—AMMONODUCT
Electrolytically zinc-coated wire—BETHANIZED
Tin plate—BETHCOLITE
Galvanized sheets—BETHCON
Continuous butt-welded pipe—BETH-CO-WELD
Copper-bearing steel sheets—BETH-CU-LOY
Tool steels—BETHLEHEM
Preformed wire rope—FORM-SET
Bolt steel—MAYARI
Low alloy, high strength steel—MAYARI R
Wire rope—PURPLE STRAND
Spring wire—SILVER STAR

Central Foundry Div., Saginaw, Mich.
Specially heat-treated malleable iron—ArmaSTEEL

Dow Corning Corp., Midland, Michigan
Silicone adhesives—DOW CORNING
Silicone rubber—SILASTIC

E. I. du Pont de Nemours & Co. Inc., Film Dept., Wilmington 98, Del.
Polyester plastic film—MYLAR

Enthone Inc., 442 Elm St., New Haven 11, Conn.
Black oxide coatings—EBONOL
Chromate conversion coating—ENTHOX
Phosphate coating—ENTHONE COMPOUND 39

Greene, Tweed & Co., North Wales, Pa.
Packings and gaskets—PALMETTO

Hitchiner Mfg. Co. Inc., Milford, N. H.
Precision investment castings—HITCHINER

Gries Reproducer Corp., 32 Second St., New Rochelle, N. Y.
Small zinc-alloy die castings—GRIES
Small zinc-alloy die castings—GRC
Small zinc-alloy die castings—INTERCAST

Page & Hall Mfg. Co. Inc., 1600 Hyde Park Ave., Boston 36, Mass.
Short-run zinc die castings—PAGE & HALL

Penn Precision Products Inc., 501 Crescent Ave., Reading, Pa.
Beryllium copper—PENNROLD
Copper alloys—PENNROLD PRECISION STRIP
Beryllium copper—PENNTEMP

Pure Carbon Co. Inc., St. Marys, Pa.
Powdered metal products—PUREMET
Carbon products—PUREBON
Carbon products—PURE

Republic Steel Corp., Republic Bldg., Cleveland 1, O.
High-strength steel—REPUBLIC DOUBLE STRENGTH
Low-phosphorus, copper-free pig iron—CHATEAUGAY
Electrogalvanized, chemically treated sheets—ELECTRO PAINTLOK
Rust-resisting copper-molybdenum iron—TONCAN
Steels—REPUBLIC

Republic Steel Corp., Alloy Steel Div., Massillon, O.
Titanium—REPUBLIC
Alloy steels—REPUBLIC
Stainless steel—REPUBLIC ENDURO

Republic Steel Corp., Union Drawn Steel Div., Massillon, O.
Cold-drawn steels—UNION

Saginaw Bearing Co., 821 S. Water St., Saginaw, Mich.
Bearing bronzes—SABECO

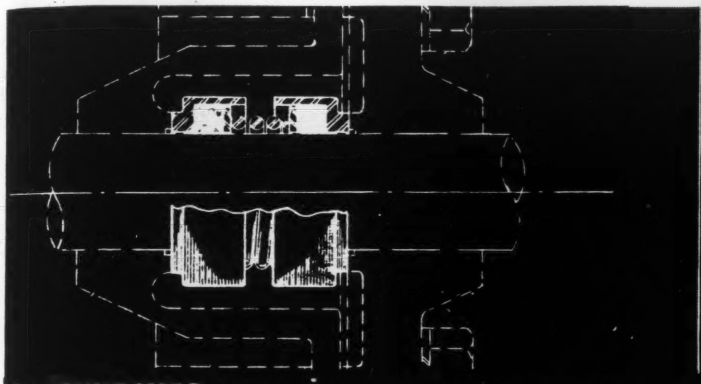
Wallingford Steel Co., Wallingford, Conn.
Steel tubing, pipe and strip—WALLINGFORD

Watertown Mfg. Co., Watertown, Conn.
Phenolic plastic molding compound—NEIL-LITE

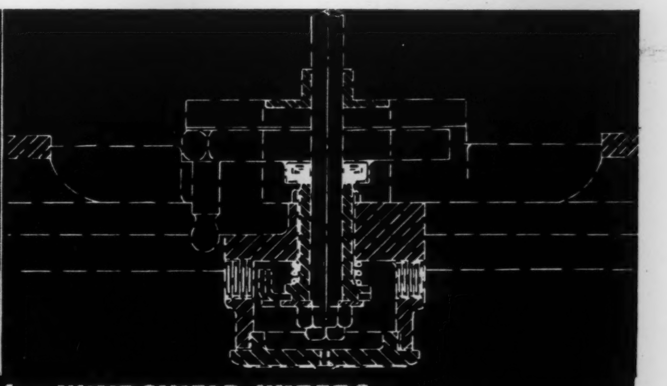
EXTRA COPIES

Extra copies of this Supplement to *Machine Design*'s 1954 *Directory of Materials* are available on request. They can be obtained by using the postcard opposite Page 220. Copies of the *Directory of Materials*, plus this Supplement, are available for $1.00 each from: Reader Service Dept., *Machine Design*, Penton Bldg., Cleveland 13, O. See advertisement on Page 235.

Shaft-Sealing problem?

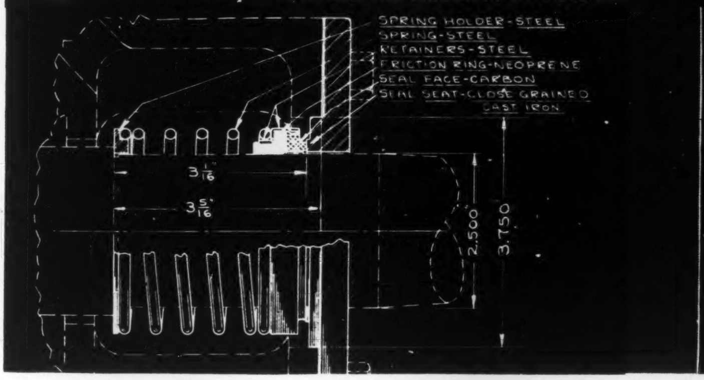


for SWITCHES

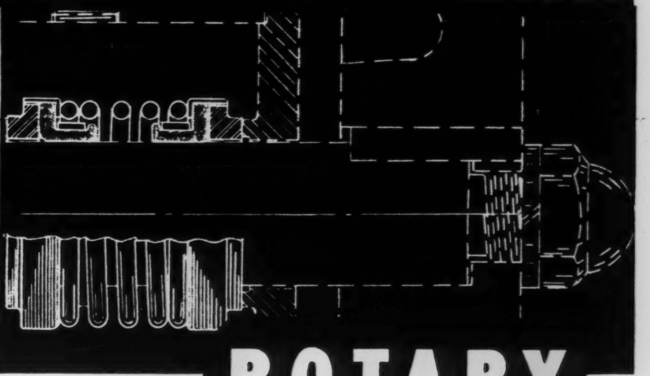


for WINDSHIELD WIPERS

for CONDENSING UNITS



for PUMPS



for the Right answer . . ROTARY SEALS

When ordinary methods won't do the job—yet *Shaft-Sealing Certainty* is a *must*—the proper ROTARY SEAL is usually the answer. ROTARY SEALS stop Shaft-Sealing troubles before they start, because they're *tailor-made* for each specific application.

The basic sealing principle originally introduced by ROTARY SEAL more than 20 years ago has naturally been imitated up to a point. But the broad experience of ROTARY SEAL engineers is inimitable. That experience makes it possible to adapt the basic ROTARY SEAL principle in just the right way—with the correct facings, springs and other details—to give you complete assurance of positive, trouble-free Seal performance under *your* conditions.

The illustrations above suggest only a few of the many successful uses of ROTARY SEALS. You'll find them "standard equipment" among leading makers of PUMPS—HYDRAULIC DEVICES—COMPRESSORS — APPLIANCES — GEAR BOXES—HEAVY DUTY WINDSHIELD WIPERS—AGRICULTURAL MACHINERY—and in scores of other applications where *Shaft-Sealing Certainty* is vital even under the most rigorous conditions.

The best time to start solving *your* Shaft-Sealing problem is at the drawing-board stage. Call in our engineers for an early consultation—and send for your copy of our brochure, *"Sealing with Certainty"*, which explains and illustrates the ROTARY SEAL principle.

THE ROTARY SEAL COMPANY
mechanical seals for rotating shafts

Shaft-Sealing with Certainty

2022 NORTH LARRABEE STREET
CHICAGO 14, ILLINOIS, U. S. A.

Helpful Literature

(Continued from Page 238)

modern electronics for military and industrial instruments. Complete list of tools and equipment is given.

35. Switches For Industry

Minneapolis-Honeywell Regulator Co., Micro Switch Div.—20-page catalog 101 entitled "Switches for Industry" covers 22 families of switches, describing 258 different switch units, actuators and enclosures. Dimensional photos, characteristics, electrical ratings and technical data are offered to aid designer in switch selection.

36. Solder & Its Usage

Kester Solder Co.—"Solder . . . Its Fundamentals and Usage" is title of 80-page treatise written and compiled by C. L. Barber, company research director. Book will provide solder user with a scientific study of the industrial application and usage of solder. Charts, tables and photos are included.

37. Hydraulic Cylinders

Lynair Inc.—Dimensional drawings on foot mount, pivot mount, front and rear flange mount, front and rear trunnion mount and side mount series H-10 hydraulic cylinders are provided in 10-page loose-leaf booklet. Nonrotating, cushioned and noncushioned models for operating pressures to 1000 psi are covered.

38. Thin Section Bearings

Kaydon Engineering Corp.—Reali-Slim bearings, including units with ¼-in. cross sections, ¼-in. width and up to 12 in. ID are described in 24-page engineering catalog 54. Listings cover units up to 1-in. cross section width and up to 40-in. ID. A section is devoted to bearings with thin flanges for mounting directly to adjoining structures.

39. Shaft Mounted Drives

Falk Corp.—Complete information, including design data, selection tables, dimensions, weights and installation photos, is given on shaft mounted gear drives in 8-page bulletin 7101. Drives are intended for machines requiring input speeds between 420 and 10 rpm in range between ½ and 30 hp.

40. Weldments

Graver Tank & Mfg. Co.—Illustrations presented in 16-page brochure on "Graver Weldments" depicts the design and range flexibility of company's facilities. Weldments are pictured for such industries as diesel engine, primary metal, mining and construction, metalworking and electrical and power machinery. Alloy work is covered as well.

41. Alemite Measuring Fittings

Stewart-Warner Corp., Alemite Div.—"Ask Anyone in Industry" is title of 24-page pocket-size booklet, which in fast-paced comic cartooning style, points up advantages of Alemite Accumeter measuring lubrication fittings. Fittings when properly installed accurately measure lubricant into each bearing according to its requirements.

42. Power Screwdrivers

Detroit Power Screwdriver Co.—Three models of power screwdrivers, including bench and pedestal types, are described and illustrated in 40-page brochure. Fixtures for nesting assemblies, motorized screw-feeding hoppers made in six diameters from 8 to 30 in., nut driving and special assembling machines are covered as well. Machines drive standard machine, wood, sheet metal and self-tapping screws with round, flat, binder, fillister or hex heads.

43. Crepe Paper Packaging

Cincinnati Industries Inc.—Stretchable, pliable X-Crepe which can be used like cloth, used instead of rubber or in place of cork is described in 4-page folder with sample sheet. This crepe paper product can be formed, creased, coated, saturated, sewn or taped, imprinted, slit and die-cut, glued or cemented, waterproofed and indented or embossed.

44. Roller Chain & Sprockets

Dodge Mfg. Co.—Technical data, prices and design information on Taper-Lock sprockets and companion roller chain are contained in 4-page illustrated bulletin A-632. Interchangeability of Taper-Lock sprockets for various shaft sizes, ease of installation without keying or reboring, and off-the-shelf availability of complete size range are discussed. Tables list complete specifications.

45. Investment Casting

W. H. Anderson Co., Mfg. Div.—Cost saving advantages of "Anderson Investment Casting" are pointed up in 4-page folder. System is described and illustrated in 9 steps.

46. Hydraulic Control Valves

Parker Appliance Co.—10-page illustrated catalog file No. 1551A presents dimensional data and outlines features of 1, 2, 3 and 4-spool models of hydraulic control valves with capacities of 8 to 35 gpm. Designed for mobile equipment applications, these valves are usable on pressures up to 2000 psi.

47. Cold-Headed Parts & Fasteners

National Screw & Mfg. Co.—Typical special products and fasteners produced to user's specifications by modern cold-heading techniques are subject of 16-page illustrated booklet 6-54. Parts shown include diesel engine push rod, flattened ball collar stud, round collar thumb screw, welding fasteners and leveling or adjusting screws. Complete engineering and production service is offered.

48. Battery & Test Clips

Mueller Electric Co.—8-page illustrated catalog No. 150 deals with Universal line of battery and test clips, clip insulators and other related products for the electronic, electrical and automotive industries. Solid copper and steel clips with capacities up to 300 amp are described in detail.

49. Hard-Facing Data

Mir-O-Col Alloy Co.—Listing the characteristics of various hard-facing electrodes and rods produced by 29 manufacturers, comprehensive comparison chart aids in selection of proper alloy for any application. Individual hardness ratings as deposited and work hardened or heat treated are tabulated.

50. Pilot Bearing Bushing

Donley Products, Inc., J. G. Jergens Div.—8-page illustrated bulletin "Live Pilot Bearing Bushings" explains how these machine tool accessories provide seal against coolants and dust, permit optimum use of carbide tools and pilot heavy loads accurately. Data are included on needle bearing pilot bushings and live centers also.

51. Diaphragm Valve

Maurice A. Knight—Acids, solvents and alkalies do not affect the Permanite diaphragm valve which is available in 1 to 3-in. sizes for pressures of 150 to 65 psi, respectively. Recommended maximum operating temperature is 180° F. Full details are given in 2-page bulletin 15.

52. Light Conveyor Belts

B. F. Goodrich Co., Industrial Products Div.—Performance and application data for line of Koroseal light conveyor belts for food handling and light industrial use are given in 4-page catalog 2640. Belts are easy to clean, resist acids and grease and withstand temperatures up to 150° F.

53. DC Power Supplies

Dressen-Barnes Corp.—Model 3-150-L low cost power supply, model D3-300E Super Precision power supply, models T-100-B and T-100-D transistor power supplies and closely-regulated development and research power supplies are subjects of four illustrated data bulletins. Capacities range up to 1000 v dc and 500 ma.

54. Torque Converter Coolers

Young Radiator Co.—Designed expressly for torque converter cooling applications, Young units are engineered for any mobile or stationary application in range of 100 to 600 hp. Oil-to-air and oil-to-water type coolers are available for cooling of power equipment using hydraulic or hydraulic mechanically-clutched transmissions. Illustrated 8-page catalog 1054 tells all.

55. Worm Gear Speed Reducers

Winsmith, Inc.—Dimensions and specifications of the C line of Winsmith worm gear speed reducers are given in illustrated bulletin HW 654. Right and left hand as well as vertical models are available in five sizes to cover the 1/100 to 5-hp range.

56. Stock Forgings

Cleveland Hardware & Forging Co.—40-page illustrated catalog 19A contains complete information on line of stock industrial and automotive forgings. Types covered include forged levers, rod ends, yokes, eye bolts, hooks and truck and body hardware. Facilities of company to produce parts to user's specifications are described.

57. Recording Oscillograph

Consolidated Engineering Corp.—12-page illustrated manual CEC-1521A deals with the type 5-116 recording oscillograph which was developed to provide the dynamic test-measurement field with a compact, accurate reliable instrument. Features include daylight-loading magazines, record speed range of ¼ to 100 in./sec, 0-300 cps galvanometers, 0.1 and 0.01-second timing lines, automatic record numbering and choice of ac or dc models.

58. Hot Extruded Alloys

Allegheny Ludlum Steel Corp.—New hot extruded shapes offered in stainless, tool steels, high temperature alloys and other steels are subject of 4-page bulletin "Hot Extrusions." Advantages of these extrusions include close tolerances, minimized scrap and adaptability to small quantity production.

59. Electric Motors & Drives

U. S. Electric Motors Inc. — Uniclosed, totally enclosed, explosionproof with and without fan, Varidrive, Synchrogear, combination variable speed and internally geared, right angle worm gear, Verticlosed Hollowshaft, vertical solid shaft, test stand and aircraft electric motors are some of the 20 principal types of improved U. S. motors that are described in detail in comprehensive electric motor catalog entitled "Life - Lengthened Power."

60. Wire Handles

E. H. Titchener & Co.—"Wire Handles by Titchener" is title of 20-page illustrated guide to aid in the selection and application of 73 different styles and types of standard handles and clips. Included is handy wire size chart which shows actual diameters of standard wire gages. Basic information is given regarding the design of special handles.

61. Split Ball Bearings

Split Ballbearing Corp.—20-page illustrated catalog No. 54 gives load and speed ratings, design data, dimensions and application information on line of split ball bearings. Easily installed because of split design, bearings are available in single and double row thin bushing, heavy duty pillow block, heavy duty ball and roller, and thin section instrument styles.

62. Sheet Metal Fasteners

Speed Stud Corp.—Details of Speed Stud spring steel sheet metal fasteners which speed assembly of fabricated metal products are shown in 1-page data sheet. These one-piece blind type fasteners are reported to have holding power of ¼-in. solid fastener. Inserted easily in hole with simple tool, they hold sheets together securely.

63. Wiring Clamps & Brackets

Thomas Associates—More than 40,000 types and sizes of bare metal and cushioned or insulated line support clamps, wire harness clamps and multiple support clamps are detailed in 68-page engineering manual No. 201G. Related items described include brackets, busbars and laminated anchor nut or reinforcing shims. Index simplifies use of manual.

NOW.. OHMITE® OFFERS RESISTORS TO MEET MIL-R-26B CHARACTERISTICS G, F, AND "V"

(HIGH-TEMPERATURE—350° C—CHARACTERISTIC)

IN A WIDE RANGE OF SIZES AND RESISTANCE VALUES

PATENTED, ALL-WELDED CONSTRUCTION!

TAB-TERMINAL TYPE
Characteristics G, F, and V

Style	Over-all length	Diameter	*Watts	††Watts
RW-29	1-3/4"	1/2"	8	11
RW-30	1"	19/32"	8	11
RW-31	1-1/2"	19/32"	10	14
RW-32	2"	19/32"	12	17
RW-33	3"	19/32"	18	26
RW-34	3"	29/32"	30	43
RW-35	4"	29/32"	38	55
RW-36	4"	1-5/16"	60	87
RW-37	6"	1-5/16"	78	113
RW-38	8"	1-5/16"	110	159
RW-47	10-1/2"	1-5/16"	145	210

FERRULE-TERMINAL TYPE
Characteristics G, F, and V

Style	Over-all length	Diameter	*Watts	††Watts
RW-10	11-7/16"	1-5/16"	140	203
RW-11	9-5/8"	1-5/16"	116	168
RW-12	7-7/16"	1-5/16"	86	125
RW-13	5-1/8"	1-1/16"	50	72
RW-14	4-7/16"	1-1/16"	40	58
RW-15	2-15/16"	3/4"	20	29
RW-16	2-3/8"	3/4"	14	20

FLAT TAB-TERMINAL TYPE
Stack Mounting)
Characteristic G

Style	Over-all length	Width of Core	Thickness of Core	†Watts
RW-20	2-1/2"	1-3/16"	1/4"	15
RW-21	3-1/4"	1-3/16"	1/4"	22
RW-22	4-3/4"	1-3/16"	1/4"	37
RW-23	6"	1-3/16"	1/4"	47
RW-24	7-1/4"	1-3/16"	1/4"	63

AXIAL-TERMINAL TYPE
Characteristics G and V

Style	Length of Core**	Diameter	†Watts	††Watts
RW-55	1-3/8"	5/8"	5	7
RW-56	2"	5/8"	10	14

*Watts free air MIL Characteristic "F" or "G" **2-1/2" wire leads
†Watts free air MIL Characteristic "G"
††Watts free air MIL Characteristic "V"

EVEN RESISTORS WITH THE FINEST WIRE SIZE (.00175) MEET THE REQUIREMENTS OF MIL-R-26B, CHARACTERISTIC "V"

The Ohmite resistor types shown at the left can withstand a continuous operating temperature of 350° C—the high temperature requirement of MIL-R-26B, Char. "V". These resistors also meet characteristics "G" and "F"—passing severe moisture-resistance and thermal-shock tests . . . withstanding sustained vibration applied for five continuous hours . . . and satisfying the requirements of many other tests.

The Ohmite line of wire-wound resistors is the most extensive on the market. Ohmite also has the most complete line that meets MIL-R-26B specifications. Specify resistors from Ohmite's wide range of types, sizes, and resistance values for your MIL-R-26B requirements and other tough jobs.

OHMITE MANUFACTURING COMPANY
3618 Howard Street Skokie, Illinois
(Suburb of Chicago)

OHMITE®

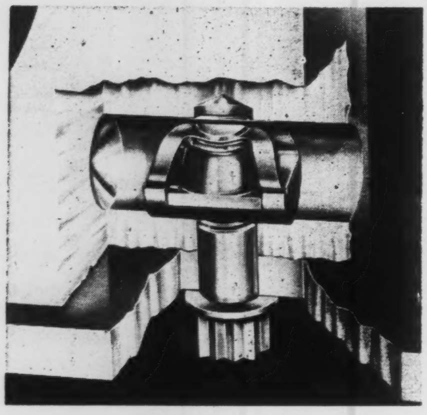
RHEOSTATS • RESISTORS • TAP SWITCHES

NEW PARTS AND MATERIALS

For additional information on these new developments, see Page 237

High-Strength Barrel Nut

Forgings and other structural members can be joined without need for large wrenching opening by means of type 2552 self-locking high tensile barrel nut. This floating action fastener is designed to withstand up to 180,000 psi at pitch diameter of bolt. Light aluminum base is used to locate the nut body which is held in place by a Rollpin self-locking pin. Complete nut assembly will move freely in the direction of the hole drilled for the nut and can move perpendicular to axis of hole 0.03-in. in either direction to compensate for any misalignment. Nut retaining clip holds unit in proper position, and the top of the clip seats automatically in the drill point of the bolt hole. Self-locking action and reuseability are made possible by integral nylon collar in the barrel nut. Nut is available in eight thread sizes from ¼-28 through ¾-16. Made by **Elastic Stop Nut Corp. of America,** 2330 Vauxhall Rd., Union, N. J.

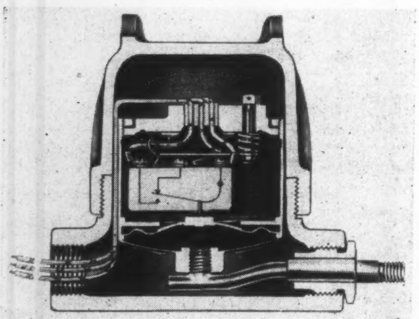


For more data circle MD-64, Page 237

Pressure Switches

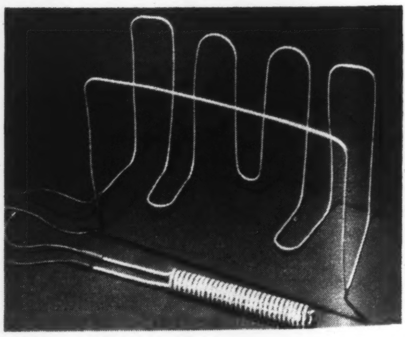
Compact pressure and vacuum switches cover the range from 30 in. of mercury proof vacuum to 150 psi pressure, sensing increasing or decreasing vacuum or pressure. Switches repeat within ±1 per cent of setting. Enclosed in an explosionproof housing, they are Underwriters' approved for hazardous locations where vapors of ethyl, ether, gasoline, alcohol, acetone, petroleum, naphtha and lacquer solvents, as well as natural gas or grain dust are present. Standard models are available for single or dual settings. The latter will secure two different pressure limits and actuate two electrically independent circuits, one ac and the other dc if desired. Units are automatically reset by snap action. Made by **Barksdale Valves,** 5125 Alcoa Ave., Los Angeles 58, Calif.

For more data circle MD-65, Page 237



Heating Units

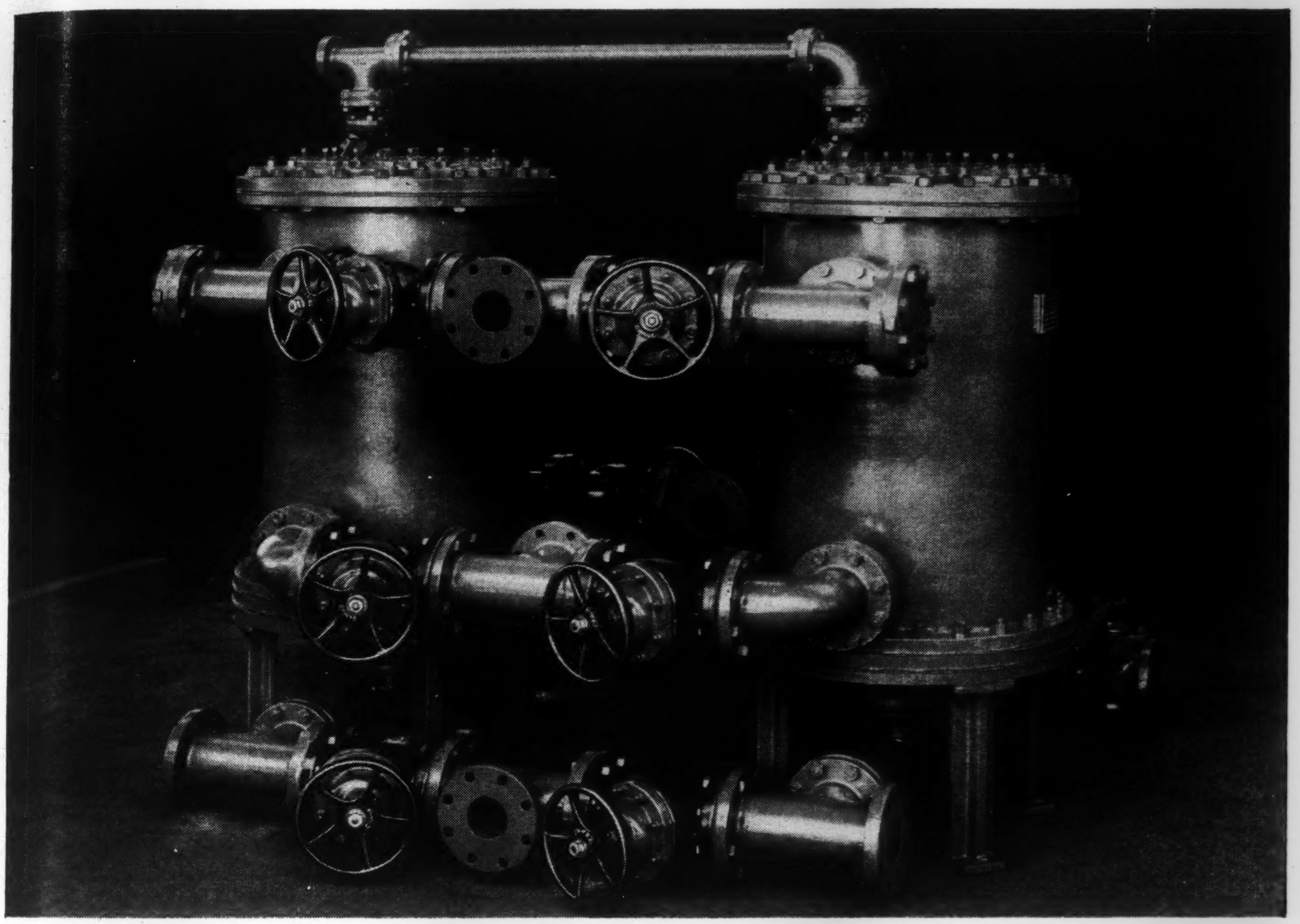
Single, low-watt density Corox heaters can be formed into shapes and sizes to effectively heat almost any surface or enclosure. They are available in continuous lengths up to 25 ft and as small as 0.23-in. OD. Neoprene covered lead wires are attached to the heater terminals and sealed under pressure to provide a positive moisture seal and mechanical strength. Materials used in fabrication of heaters include copper, steel, aluminum, Incaloy and Inconel, as well as other alloy tubings. Made by **Westinghouse Electric Corp.,** P. O. Box 2099, Pittsburgh 30, Pa.



For more data circle MD-66, Page 237

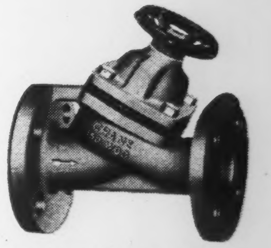
Double Solenoid Valve

Provision for momentary contact for reversal of valve position in both positions eliminates need of a holding relay in the Speed King double solenoid pilot-operat-



Another good product design with the Crane "label"

Several years ago a southwest chemical plant was plagued by sand clogging their spent brine disposal wells. To correct the condition, the R. P. Adams Company, Inc., of Buffalo, N. Y., installed two CRF-5 rubber-lined filters with rubber-lined Crane Y-pattern diaphragm valves and rubber-lined fittings and pipe. The trouble-free service of the original units in handling this corrosive fluid was the contributing factor in the recent purchase of two additional and identical filters.



Crane Y-Pattern Diaphragm Valves . . . preferred for safety and versatility. Crane design assures long diaphragm life, positive shut-off in case of diaphragm failure, accurate seating, better flow control. Easy to operate . . . simple to maintain. Choice of body, trim and lining materials. Screwed and flanged end patterns. Sizes up to 6 inch.

Good Piping Design Begins Here . . . Your Crane Catalog

CRANE
VALVES
FITTINGS
PIPE
FABRICATED PIPING
55
CRANE CO.

To protect the working value of *your* product design, remember that Crane assures high quality in every piping item . . . offers the world's most complete selection . . . provides all the general information and technical data you need for quick and easy specification. Whatever you need in piping, you'll find it in your Crane Catalog.

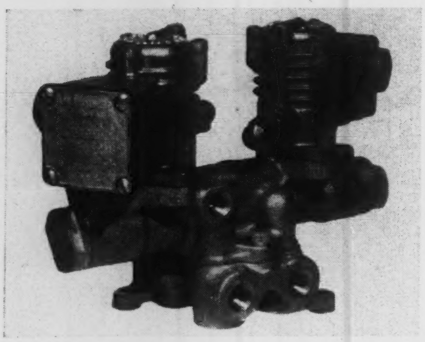
THE BETTER QUALITY... BIGGER VALUE LINE... IN BRASS, STEEL, IRON

CRANE VALVES

CRANE CO., *General Offices:* 836 S. Michigan Ave., Chicago 5, Illinois
Branches and Wholesalers Serving All Industrial Areas

for the
THRIFTY
BUYER
and Specifier

VALVES · FITTINGS · PIPE · PLUMBING · HEATING



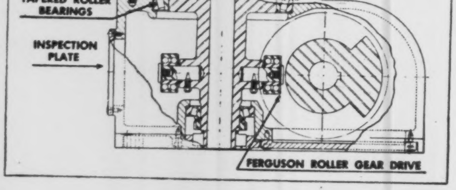
ed control valve. Once the stem has been positioned, it remains in that position until the solenoid is energized to reverse it. Both pilots are normally open, reversal being accomplished by exhausting air on one end of the stem or the other. Valve is made in both foot and manifold mounting types in basic ⅜ and ¾-in. sizes and in a four-way body. Standard pressure range is 35 to 200 psi. Overall dimensions are 3 x 5 x 8 in. Manual override for operation in both directions, junction box and external pilot supply are optional. Made by **Valvair Corp.,** 454 Morgan Ave., Akron 11, O.

For more data circle MD-67, Page 237

Index Tables

Standard high-speed tables are available with 4, 6, 8 or 12 stops and with dial sizes varying from 12 to 36 in. diameter. Variations in movement time range from ¼ to ¾ of the total cycle. Design permits passage of air or hydraulic fluid through the roller gear shaft and dial to the work area for actuation of product holding devices, or cooling water for dissipation of heat in operations such as induction welding. Brackets outside the dial periphery permit attachment of tooling such as drilling and tapping heads, staking presses and other forming, assembly and inspection devices. With a Ferguson Roller Gear Drive as the indexing mechanism, this Intermittor can attain high speeds without sacrifice of product quality. Acceleration, self-locking and zero backlash characteristics permit smooth starting and stopping without auxiliary locking methods, even at speeds as high as 500 indexes per minute. Made by Roller Gear Div., **Ferguson Machine & Tool Co.,** P. O. Box 191, St. Louis 21, Mo.

For more data circle MD-68, Page 237



Precision Snap Switch

Unimax series WHB precision snap switches combine maximum movement differential of 0.0005-in. and low actuating force with high repeat accuracy. Units are suitable for use in pressure-sensitive thermostatic controls and short-motion gaging devices. Basic WHB-5 switch is 1 15/16 in. long, 15/16 in. high and 11/16-in. wide. It is UL listed for 15 amp, 125/240/480 v ac. Three styles of over-travel plungers are available. Step base facilitates use of standard connector lugs, or merely looping connecting wires around the 6/32 binding head screws. Made by Unimax Div,. **W. L. Maxson Corp.,** 460 W. 34th St., New York 1, N. Y.

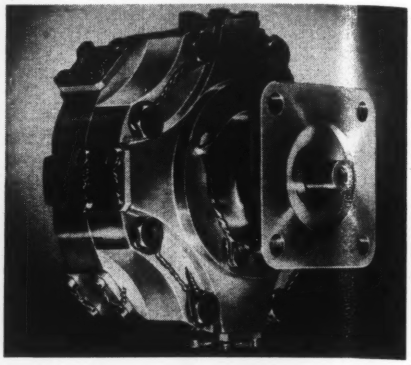
For more data circle MD-69, Page 237

UNIMAX PRECISION SWITCH
PAT NO 2521018
NEW YORK

Hydraulic Motor

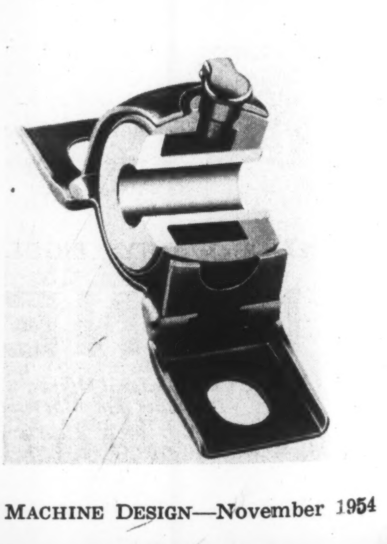
Radial type hydraulic motor built to aircraft standards is practical for use where speed and long operating life without maintenance are required. Unit operates between 1000 and 1700 psi input and will turn up 5000 rpm at latter input with rating of 2.9 hp. It measures 4¾ x 4 7/32 in., weighs under 4 lb and is suitable for use with all commercial mineral base hydraulic fluids. Each piston acts as valve for adjacent cylinder. Antifriction bearings and leakproof shaft seal are used. Motor runs equally well in either direction, reverses instantly and has almost constant torque over entire speed range. Made by **Sierra Engineering Co.,** 123 E. Montecito Ave., Sierra Madre, Calif.

For more data circle MD-70, Page 237



Sintered Bronze Bearings

Oil metered through Permawick sintered bronze bearings of pillow block and flange types provides proper lubrication to the shaft. Wicking material holds nine times its weight in oil and releases oil reluctantly upon demand. Pillow block consists of cast ball carrying the bronze bush-



FREE! time-saving slide rule...

ALEMITE
OIL-MIST DATARULE
System Limitations
Bearing Inches – 30
System Rating – 36
Use Condensing Fitting Suffix for Bearing Sizes shown below, not to exceed 30 Bearing Inches.
Basic Application Data
Bearing Diameter
Fitting Suffix No.
Maximum Number Fittings/System
Formula:

helps you design the advantages of

ALEMITE OIL-MIST

into any machine...in minutes!

Here's the simple, easy way to specify Alemite Oil-Mist—to make sure your machines have the tremendous advantages offered only by this most modern method of lubrication.

It's easy to measure the lubrication requirements of *any* machine you are designing! Just set the Oil-Mist slide rule as required—for anti-friction bearings, plain bearings, slides, ways, vees, chains or gears—and immediately the proper application information appears.

You see at a glance the type of fitting to use—how to compute bearing surface—how to take full advantage of the amazing capacity and flexibility Oil-Mist offers you! Includes basic lubricant recommendations and a complete schematic diagram showing tubing, fittings, tees, unions.

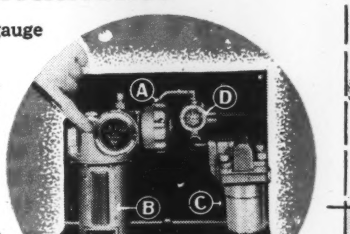
Save time and work in specifying and detailing Oil-Mist, the most efficient machine lubrication ever devised! Clip, fill out and mail coupon NOW. Supply limited!

Alemite Oil-Mist offers these lubrication advantages

Automatic Lubrication • Continuous Lubrication
Eliminates Guesswork • Greater Safety • Cuts Oil Consumption up to 90%
Extension of Bearing Life • Stops Oil Drippage • Reduction of Bearing Temperatures • Manpower Savings • Elimination of "Down-Time"
Reduction in Number of Lubricants • Protection from Contamination

LUBRICATOR SPECIFICATIONS:

- Oil-Mist outlet ½" fem. p.t. Air gauge registers to 50 psi. Operating air pressure—5 to 20 psi.
- Air regulator (A) reduces from pressures up to 200 psi. Normal air consumption—.7 to 1.2 cfm.
- Range of oils handled—to 1,000 sec. (S.U.V.) @ 100°F.
- Oil reservoir (B) capacity 12 oz. (approximately 1 week supply). Intake filter screen—70 mesh. Fill plug—9⁄16".
- Material—die cast aluminum body with nylon plastic window.
- Baffle-type water separator (C)—automatic self-dumping. Requires no manual attention—no filter elements to replace. Air inlet ¼" fem. p.t.
- Solenoid Control (D) starts system automatically when machine starts—foolproof.



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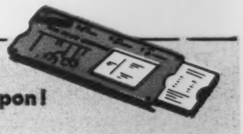
Alemite OIL-MIST Lubrication

Delivers Oil to Bearings 3 Ways!

Oil-Mist Fittings bring the most efficient lubrication in the world to any anti-friction bearing—ball, roller or needle.

Spray Fittings are recommended for open and enclosed gears and chains. Allow for a concentrated spray of oil where it is needed.

Condensing Fittings apply oil in liquid form to plain bearings, slides, ways, vees, cams and rollers.



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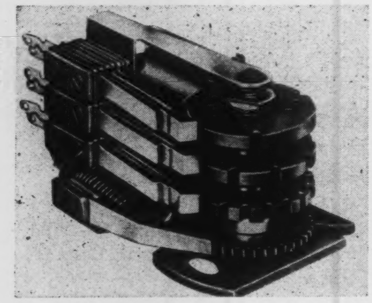
ing, oil reservoir and oil cup; a snap-lock top prepunched with holes at right angles for mounting in any position; and a base that can be bolted or welded in position. It is interchangeable with pillow blocks now in use. Both pillow blocks and flange bearings are made in ½, ⅝, ¾, 15/16 and 1-in. bore sizes and blocks are also available in 1 3/16 and 1¼-in. bores. Made by **Tann Corp.,** Congress Drives Div., 3750 E. Outer Dr., Detroit 34, Mich.

For more data circle MD-71, Page 237

Cam Type Relay

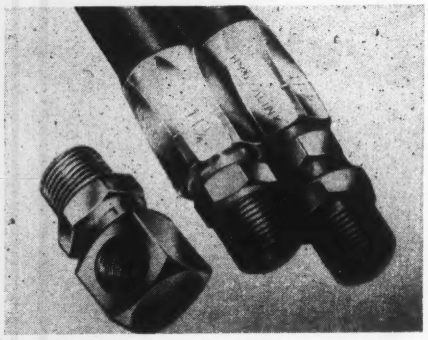
Small, lightweight and resistant to shock, vibration and temperature changes, series OCS single cam type rotary relay combines relay and stepping switch functions. It is adaptable for alternate on-off operations as well as for stepping operations. It can be driven self-interruptedly to produce a time cycle or for "homing." Available from **Automatic Electric Sales Corp.,** 1033 W. Van Buren St., Chicago 7, Ill.



For more data circle MD-72, Page 237

Hydraulic Fittings

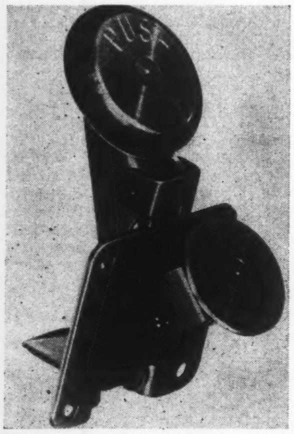
Reusable, high-pressure Hydralink couplings are available in a standard range of sizes for both one and two-wire braided, rubber covered hose. Requiring no special tools for assembly, couplings withstand pressures greater than rated burst pressures of the wire braid hose. Both fixed and swivel male end couplings are available. Adapters and fittings for all standard installations are also available. Leakproof 90-deg swivel elbows for high-pressure hydraulic equipment are available in a full range of sizes for all standard applications. These elbows can be adjusted to any angle in their relationship to the other connections. Available from **Condamatic Co. Inc.,** Sales Export Div., 332 W. 21st St., New York, N. Y.



For more data circle MD-73, Page 237

Flush Latches

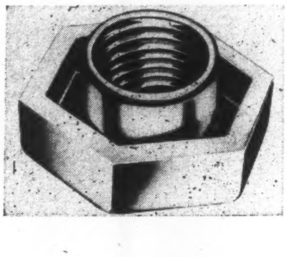
Quick-opening flush latches for access doors and panels function at extreme high and low temperatures. Large latch button can be used as a handle for opening or closing, and over-center or toggle action movement assures positive door closing or opening with only slight pressure. For applications involving moisture, the latch is available with rubber gaskets around the opening, making it splashproof, moisture resistant and dustproof. Latches are constructed of corrosion resistant stainless steel. Installed without special punches or tools, they can accommodate a wide range of thicknesses and doors. Made by **Modern Aviation Co.,** 2812 S. Main St., Los Angeles 7, Calif.



For more data circle MD-74, Page 237

Lightweight Hex Nut

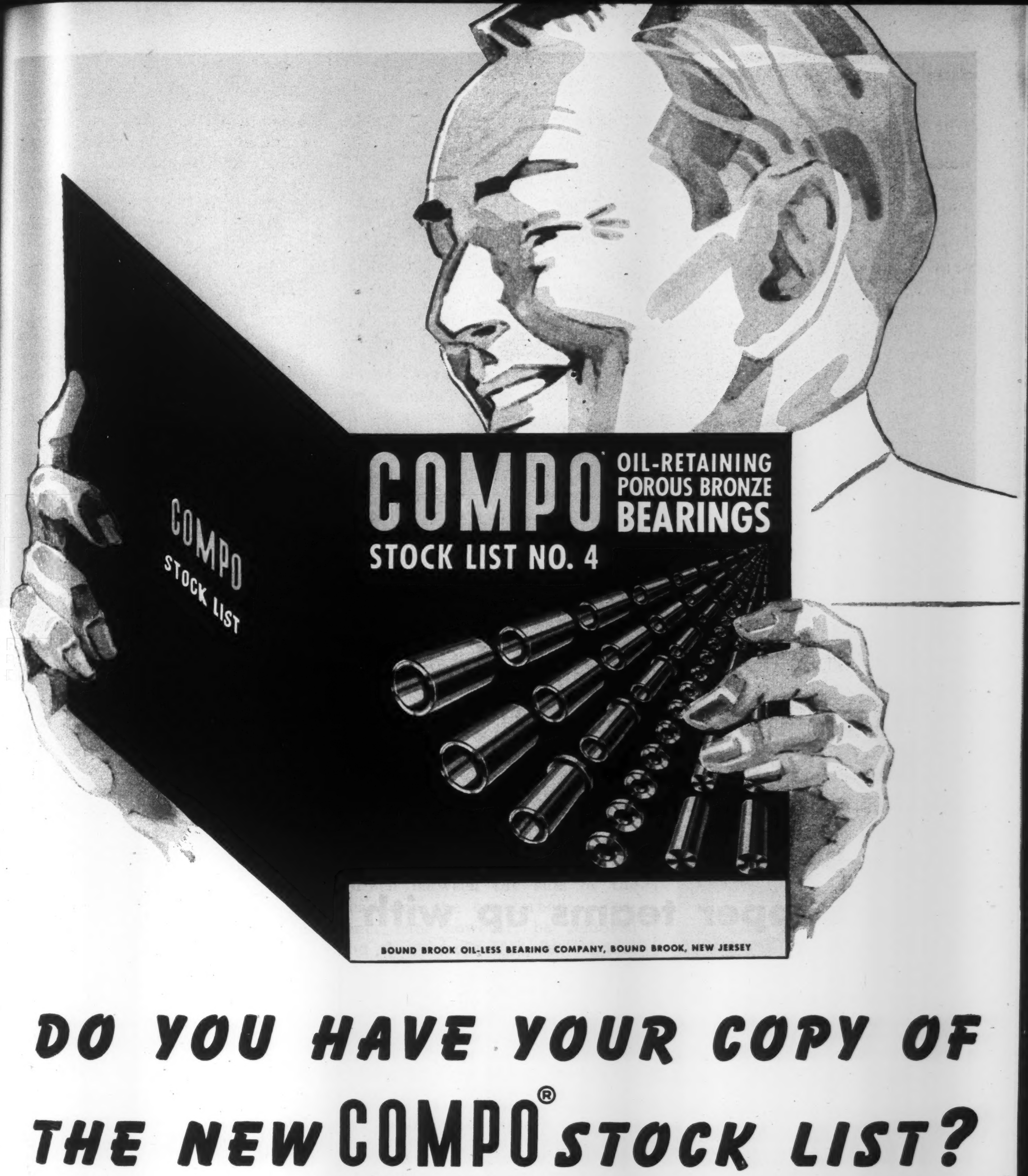
Lightweight Kaylock hex nut with high axial strength exceeds all BUAER and USAF requirements for AN363 high temperature nut and the AN365 standard hex nut, yet is dimensionally interchangeable with the AN364 thin shear nut. Of cadmium plated spring steel construction, nut has locking design wherein upper threads are made elliptical and resilient, allowing all threads to carry load without auxiliary locking device. It withstands temperatures up to 550 F. Nut is available in 6-32, 8-32, 10-32, ¼-in.-28, 5/16-in.-24, ⅜-in.-24 and 7/16-in.-20 sizes. Made by **Kaynar Co.,** Kaylock Div., 820 E. Sixteenth St., Los Angeles, Calif.



For more data circle MD-75, Page 237

Small Motors

Totally enclosed fractional horsepower motors for shaft-mounted fans and blowers weigh 50 per cent less than previous models. Extended through-bolts provide solid mounting face beyond surface of end shield. Resilient rings on bearing housings and optional resilient base make possible wide variety of mounting arrangements. Designed for moderate thrust applications, motors are available in one and two-speed, single-phase models and in single-speed polyphase models with ratings up to ½-hp. Ball bearings are offered for heavy-thrust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COMPO OIL-RETAINING POROUS BRONZE BEARINGS
STOCK LIST NO. 4
BOUND BROOK OIL-LESS BEARING COMPANY, BOUND BROOK, NEW JERSEY

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POWDER METALLURGY BEARINGS + PARTS

Because 5,000 volts like to jump— Copper teams up with *Synthane*

Properties of Synthane

In addition to those mentioned in the text, Synthane has the following important properties:

Light weight. Synthane is a dense material, but light in weight. Synthane is only about one-half the weight of aluminum.

Low moisture absorption. Most grades of Synthane are highly moisture resistant. Special grades are available for applications where absorption must be at a minimum.

Thermosetting. Synthane will hold its shape under elevated temperatures; some grades resist up to 400° C. Synthane cannot be reheated and re-shaped. (If this must be done, special post-forming grades are available.)

Availability. In addition to more than 33 grades of sheets, Synthane is also supplied in many grades of rods, tubes and special shapes. Molded-laminated and molded-macerated parts are also manufactured. A complete fabricating service is available.

● Insulating high-voltage bus bars and covering the flexible joints between them presents problems. The insulation must have high dielectric strength and high mechanical strength combined. *Synthane* laminated plastics supply these properties—and a few more. For instance, the postforming properties of paper-base *Synthane* made it possible to make the two halves of the cover economically. And *Synthane* is easily sprayed with, or laminated to, a conductive coating for corona protection.

The high dielectric strength of *Synthane* sees service in hundreds of electrical applications. *Synthane* is used in toasters, in the world's largest power shovels, and for components of TV cameras and sets. It is also used in radio transmitters and receivers, ignition systems, household appliances, electrical measuring instruments and x-ray machines.

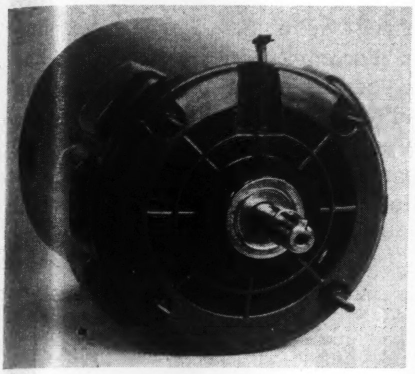
But this is only part of the *Synthane* story. The many chemical, mechanical and electrical properties of *Synthane—in combination*—have widened its field of usefulness. If you have need of a material with many different properties in combination, *Synthane* may be your answer. The *Synthane* catalog supplies full information on the grades and kinds of *Synthane* sheets, rods, tubes, special shapes and fabricated parts. Write for your copy to Synthane Corporation, 5 River Road, Oaks, Pa.

Our 25th Year

SYNTHANE CORPORATION, OAKS, PA.

SYNTHANE

LAMINATED S PLASTICS

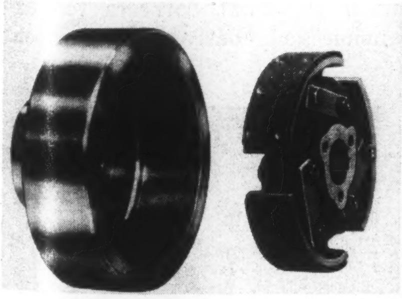


applications. Filtered oil keeps bearing surfaces clean in the all-angle sleeve bearings. Made by General Purpose Component Motor Dept., **General Electric Co.**, Schenectady 5, N. Y.

For more data circle MD-76, Page 237

Clutch Coupling

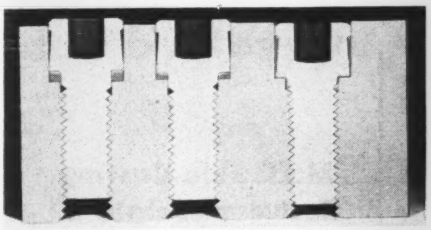
Flexible in all directions, Twiflex automatic centrifugal clutch coupling provides full centrifugal action while operating under relatively great misalignment as a direct coupling between two shaft ends. Unit consists of a driving hub, a driven drum and a series of shoes suspended between them on links attached to the shoes and hub by means of bonded rubber joints. Coupling absorbs shock, limits torsional vibration, protects driver and driven mechanisms against overload shock, and prevents torsional resonance. Available in automatic free-wheeling and automatic backstop types, couplings are made in popular size ranges for coupling two shafts; as clutches suitable for mounting on a shaft and carrying gears, pulleys, sheaves or sprockets; as centrifugal speed governing brakes and as backstops to prevent reverse rotation. Made by **Hilliard Corp.**, 102 W. Fourth St., Elmira, N. Y.



For more data circle MD-77, Page 237

Socket Screw

Blue Devil vibration and leak-proof socket head capscrew resists leakage of oil, air and water under severe operating conditions. Tests have shown resistance to hydraulic pressures of 6000 psi. Designated Led-Lok because of wedge-action principle, screw has a tapered chamfer shoulder, beneath which is a preassembled ⅛-in. lead washer. As shown in the illustration, the washer locks and seals the head of the screw by extruding and forming a wedge as the screw is tightened into place. A permanent lock and seal is thus formed between the side of the head and the counterbore. Fastener can, however, be removed and then restored to its original position without loss of desirable characteristics. Screw will not strip tapped holes of aluminum and brass parts. Made by **Safety Socket Screw Co.**, 6501 Avondale Ave., Chicago 31, Ill.

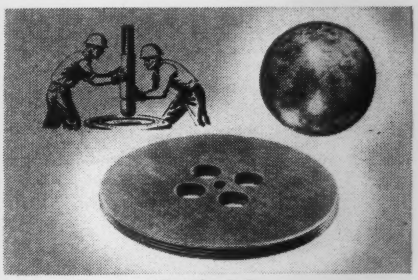


For more data circle MD-78, Page 237

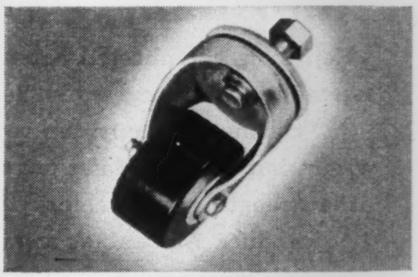
Self-Sealing Couplings

For high-pressure, heavy-flow applications, quick-sealing leak-proof hose couplings have built-in single or double check valves. One or both ends of the hose line are sealed closed, depending upon which type is used, the instant the coupling is opened. Check valves open automatically when couplings on end of fluid line are joined. Internal spring keeps

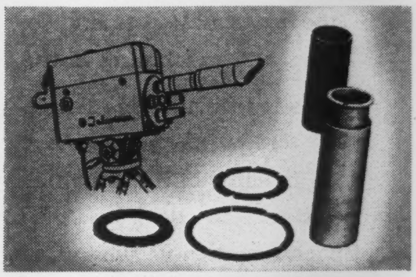
SYNTHANE
S
laminated
plastics at work



In the oil fields *Synthane's* toughness, dimensional stability and chemical resistance are all utilized in underground equipment for cementing oil wells. *Synthane* piston rings are widely used.



In business offices *Synthane* is a favored material for casters which are tough, durable and kind to various types of flooring. Many business machines, big ones and little ones, are mounted on molded-macerated wheels and casters of *Synthane.*



In television studios TV cameras use many *Synthane* parts. The mechanical strength, dielectric strength and ease of fabrication of *Synthane* all fit it for use in TV cameras, transmitters and home receivers.

What's Your PROBLEM?
MAIL COUPON FOR FREE FOLDER

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5 River Road, Oaks, Pa.

Please send me your free folder describing advantages, properties, uses and kinds of *Synthane* plastics.

Name__________
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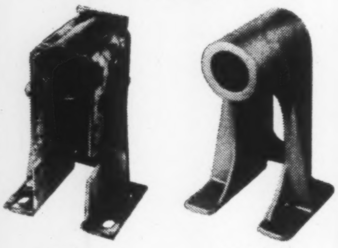
Malleable?

Streamlined Castings Save Weight
Cut Production Costs

Replacing complicated expensive assemblies with accurate malleable castings not only can reduce weight but often actually increases the strength and durability of the product. Malleable's versatile castability permits it to be cast in intricate shapes close to final form, making possible streamlined design to improve product appearance. Malleable's excellent machinability means trouble-free and low-cost machining in the shop.

Take advantage of malleable iron's remarkable combination of machinability, toughness and resistance to shock and corrosion. Specify malleable when designing new products or looking for ways to improve present production.

Malleable Casting Reduces Weight of Roller Guide 26%



22.15 lb. Fabricated Assembly

16.30 lbs. Malleable Casting

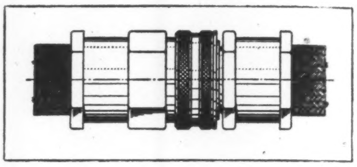
Replacing the fabricated elevator safety device roller guide with a malleable casting of equal strength saved 5.85 lbs. per guide.

Send for "Malleable Iron Facts No. 47". Tolerances and specifications of malleable castings to help you design for malleable. Ask your malleable casting supplier or write to the Malleable Founders' Society.

Malleable
FOUNDERS' SOCIETY

1800 Union Commerce Building
Cleveland 14, Ohio

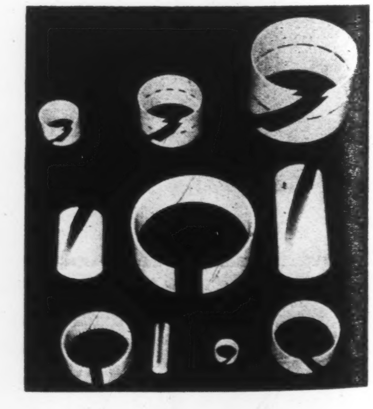
check valve closed when coupling is disconnected. End of fluid line is sealed tight by gasket ring on valve. Interchangeable female pipe thread, male pipe thread, expansion ring and barb shank coupling styles are available. Full swiveling design prevents kinking of hose. Bearing surfaces are heat treated, and ball bearings and springs are stainless steel. Eight standard sizes from 1/4 to 2 in. are available from stock, and ten special sizes from 2½ to 12 in. can be supplied on order. Standard construction includes cadmium plated steel with Neoprene and Buna-N seals. Aluminum, brass, stainless steel and alloy constructions are available with special seal materials. Made by **Titeflex Inc.,** 500 Frelinghuysen Ave., Newark 5, N. J.



For more data circle MD-79, Page 237

Bearing Liner

Heretofore available only in combination with metal bearing shell, Nylined nylon bearing liners may be installed directly in equipment. Two types of liners include one that is used in standard bearings for applications requiring lubrication. It has spiral compensation gap that corrects for expansion and contraction of nylon.



new variable vane feature adds more advantages to NORGREN

micro-fog lubricators

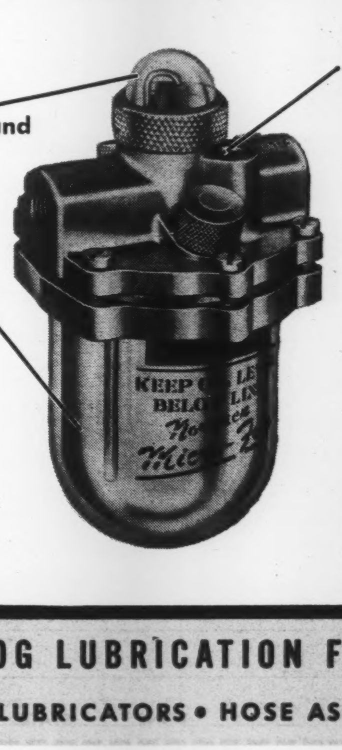
for air tools and cylinders

meet a broader range of operating conditions...each can handle jobs now done by several sizes of lubricators

¼"	5 to 40 cfm
⅜" & ½"	5 to 100 cfm
¾" & 1"	5 to 250 cfm

simple adjustment inside the dome of the lubricator provides wide range of air flow for varying conditions or different applications, which previously required several lubricators: For instance, at 80 psi. the ⅜" size can be easily set for a low flow range of 5 to 9 cfm or up to a high flow range of 50 to 100 cfm, or any comparable intermediate range. Transparent bowl (½ pt.) or tank types (1¾ or 4½ gal.)

OTHER EXCLUSIVE FEATURES OF NORGREN MICRO-FOG LUBRICATORS



360° visibility of both the oil feed and oil supply ...no guess work.

oil feed controlled by auxiliary air circuit ...gives an accurate and uniform rate of oil feed.

constant oil level ..rate of oil feed not affected by oil supply.

(Available in all types but not shown here)

WRITE FOR DETAILS IN FORM 496

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PIONEER AND LEADER IN OIL-FOG LUBRICATION FOR 26 YEARS

VALVES • FILTERS • REGULATORS • LUBRICATORS • HOSE ASSEMBLIES

Best Medicine
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Here's a "miracle drug"
proved throughout industry!
℞ for all threaded
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*Heli-Coil** Screw Thread Inserts.

These 18-8 stainless steel or phosphor bronze ***Heli-Coil*** Inserts give you a minimum of 25% greater loading strength... your threads will *never* seize, corrode, or gall... you save space, material and money because you can use fewer, smaller, shorter fastenings and lighter, cheaper materials... and smaller bosses and flanges.

It will pay you to investigate the many advantages ***Heli-Coil*** Screw Thread Inserts offer. Write today for full information, free samples and, if you wish, the assistance of a ***Heli-Coil*** Thread Engineer.

***Heli-Coil* Inserts conform to official Military Standards MS-122076 (ASG) through MS-124850 (ASG) and others.**

* Reg. U. S. Pat. Off.

HELI-COIL CORPORATION
131 SHELTER ROCK LANE, DANBURY, CONN.

☐ Send samples and Bulletin 689 — Military Standard Sheets.
☐ Please have a *Heli-Coil* Thread Engineer call.
☐ Send samples and Catalog.

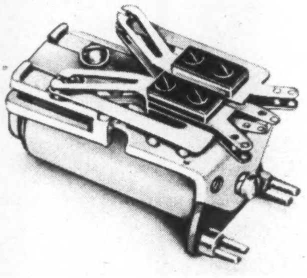
NAME__________ TITLE__________
COMPANY__________
ADDRESS__________
CITY__________ ZONE______ STATE______ 2709

Interlocking portions prevent loss of oil from ends of bearing after it has been circulated through oil distribution slot. Second type is simplified liner with straight or spiral compensation gap. It has no interlock or oil distribution grooves. Various methods for retaining liners in equipment have been devised. Made by **Thompson Industries Inc.,** Manhasset, N. Y.

For more data circle MD-80, Page 237

Miniature Relay

Reliable switching of extremely low voltage and low current is accomplished by series 22 miniature relays which have twin contacts. Flexibility of the long contact springs enables twin points to make contact independently. Thus, one point will make contact even when other is blocked by dust or grit. Relays are available for ac or dc, in open types, as well as with hermetically sealed and dust-tight enclosures. Made by **Magnecraft Electric Co.,** 1442-M W. Van Buren St., Chicago 7, Ill.



For more data circle MD-81, Page 237

Hydraulic Cylinders

Minimum installation space is required for line of general purpose industrial hydraulic cylinders as a result of the use of square rod end and head end caps that house pipe connections. Cylinders comply with JIC standards and are rated at 2000 psi. Adjustable hydraulic cushions on either or both ends can be furnished to decelerate piston rod movement. Multiple positioning

weight lifters aren't always available

KEEP YOUR PRODUCT

Lightweight!

Power Products new industrial engine offers

60% less engine weight

42% less engine size

NOW you can give your power equipment the Lightweight being demanded by all of industry. Power Products engines are not just a little lighter—they're 60% lighter than any currently available industrial engine of comparable horsepower . . . and that means greater portability for equipment. Wheels, carriages, etc., formerly necessary for portability, can be eliminated in many cases, allowing further streamlining and extra weight and cost savings.

Power Products engines are more compact in design — easy starting — offer sustained performance at high speeds and are easier to service than any other industrial engines. Yet they actually cost less!

If you want better acceptance — better performance for any industrial product that requires from 2 to 4 horsepower . . . switch to Power Products Lightweight!

LOOK AT THESE FEATURES

Lightweight — A standard 3⅓ H. P industrial engine weighs as much as two and one half Power Products industrial engines of 3½ H. P.

Compact — A unique design makes this engine amazingly compact. A comparison of overall dimensions shows a saving of 72% in size over the standard engine.

LOOK AT THE RESULTS — "Pump and motor weigh only 25 lbs.," reports a leading pump manufacturer This is typical of the kind of amazing lightweight products these engines make possible.

"Only 41 lbs., and usable anywhere, at any angle." Grain auger manufacturers are among the many who have found it possible to revolutionize their products with these engines.

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Gentlemen:

I know what important advantages weight saving can give my products. Please send me full information on these new engines.

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HOW TO PICK
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FOR THE JOB

TUTHILL *Simplifies Pump Selection*
for PRODUCT DESIGNERS

To make it easy for product designers to select the right oil pump for the job, Tuthill offers new catalog data covering pump models to meet the specific pumping purposes outlined below. Each catalog features an individual pump guide so you can select the exact pump to fit your need. Check the following services and ask for the Tuthill catalogs you wish by Catalog number indicated.

For PRESSURE LUBRICATION

		Catalog No.
Model L	⅓ to 6 g.p.m. up to 200 p.s.i.	101
Model C	2 to 200 g.p.m. up to 100 p.s.i.	102
Model R	¾ to 200 g.p.m. up to 100 p.s.i.	105
Models S & SA	⅓ to 200 g.p.m. up to 200 p.s.i.	106

For HYDRAULIC SERVICE

		Catalog No.
Model L	⅓ to 6 g.p.m. up to 600 p.s.i.	101
Model CK	5 to 200 g.p.m. up to 400 p.s.i.	103
Model R	¾ to 200 g.p.m. up to 400 p.s.i.	105
Models S & SA	⅓ to 200 g.p.m. up to 200 p.s.i.	106

For COOLANT SERVICE

		Catalog No.
Model C	2 to 200 g.p.m. up to 100 p.s.i.	102
Model CK	100 to 200 g.p.m. up to 200 p.s.i.	103
Model M	2 to 50 g.p.m. up to 15 p.s.i.	104
Model R	2 to 200 g.p.m. up to 100 p.s.i.	105
Models S & SA	2 to 200 g.p.m. up to 200 p.s.i.	106

For TRANSFER AND CIRCULATING

		Catalog No.
Model L	⅓ to 6 g.p.m. up to 200 p.s.i.	101
Model C	2 to 200 g.p.m. up to 100 p.s.i.	102
Model CK	100 to 200 g.p.m. up to 200 p.s.i.	103
Model R	2 to 200 g.p.m. up to 100 p.s.i.	105
Models S & SA	2 to 200 g.p.m. up to 100 p.s.i.	106

For BURNING OILS

		Catalog No.
Model L	⅓ to 6 g.p.m. up to 200 p.s.i.	101
Model C	2 to 50 g.p.m. up to 100 p.s.i.	102
Type SU	2 to 50 g.p.m. up to 300 p.s.i.	107

For BUILT-IN APPLICATIONS

All standard Tuthill Pump models are available in stripped form for building into the design of your equipment. Ask for Catalog No. 106.

TUTHILL PUMP COMPANY
Dependable Rotary Pumps since 1927
939 East 95th Street, Chicago 19, Illinois
Canadian Affiliate: Ingersoll Machine & Tool Co., Ltd.
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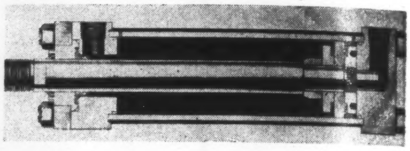
TUTHILL
PUMPS FOR THE PURPOSE

New Parts



of ports and air vents and option of foot, flange (head or rod end), extended tie rod and clevis mountings permit mounting flexibility. Standard sizes from $1\frac{1}{2}$ to 6 in. bore with standard or heavy duty piston rods are available. Made by **Waterbury Tool Div., Vickers Inc.,** 1400 Oakman Blvd., Detroit 32, Mich.

For more data circle MD-82, Page 237

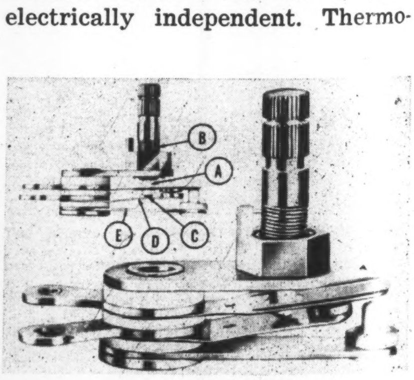
Rust Preventive

Applied by brush, End-O-Rust coating bonds to any iron or steel surface that is dry, free of grease and loose scale and not painted with a tar or bituminous paint. High in zinc content, it cold galvanizes mechanically and electrochemically even rusty surfaces. Made by **Industrial Craftsmen Inc.,** 145 High St., Boston 10, Mass.

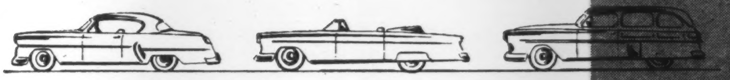
For more data circle MD-83, Page 237

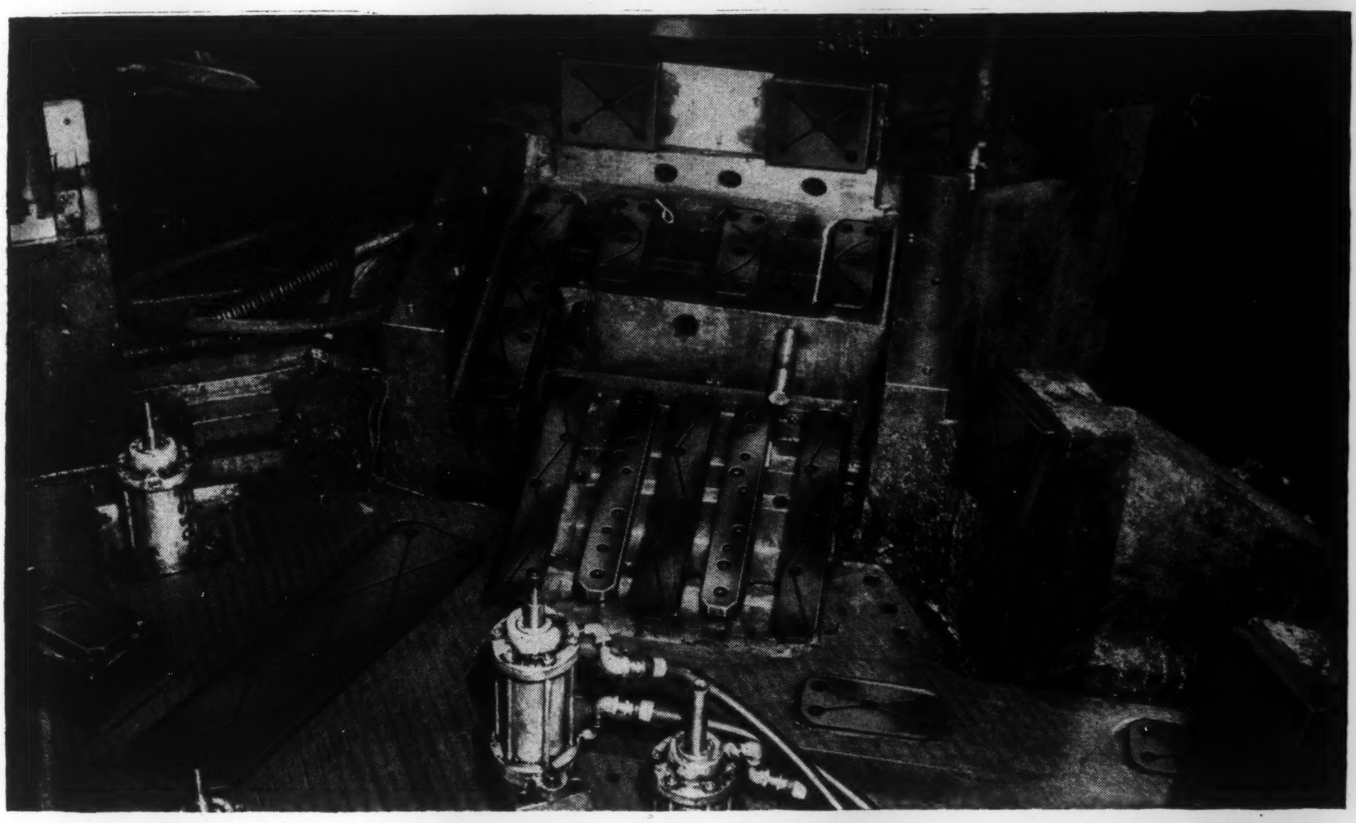
Bimetal Thermostat

Pin type construction of Stemco type S and snap-acting type SA bimetal thermostats offers virtually linear operation over thousands of cycles because calibration is unchanging. Steatite pin (A) inserted in lower end of adjusting stem (B) carries a hardened steel pin (C) which applies adjustment pressure against contact spring member (D). Strip bimetal thermal member (E) is electrically independent. Thermo-



IT'S OK WHEN YOU FOLLOW THE LEADERS





The automotive industry stands as a leader in technological advancement and cost-cutting production techniques. That's why today practically every important automobile manufacturer is using Ohio Knife Aluminum Bronze Wear Plates on body dies.

By a unique clading process, long-wearing aluminum bronze is bonded to a machinable steel base. Cost is drastically lower when compared to solid cast bronze plates. A finer quality bearing surface is obtained, resulting in longer life. When fitting is required to suit die, steel backing of plate is easily machinable, and no difficulty is encountered drilling or counter boring through bronze surface. OK aluminum bronze plates are applicable wherever a die has a sliding or cam action. A large selection of OK aluminum bronze plates carried in stock . . . finished ground, flat and parallel . . . ready to ship. Specials made to your specifications. Literature available showing our standard sizes. Write Dept. 29-A.

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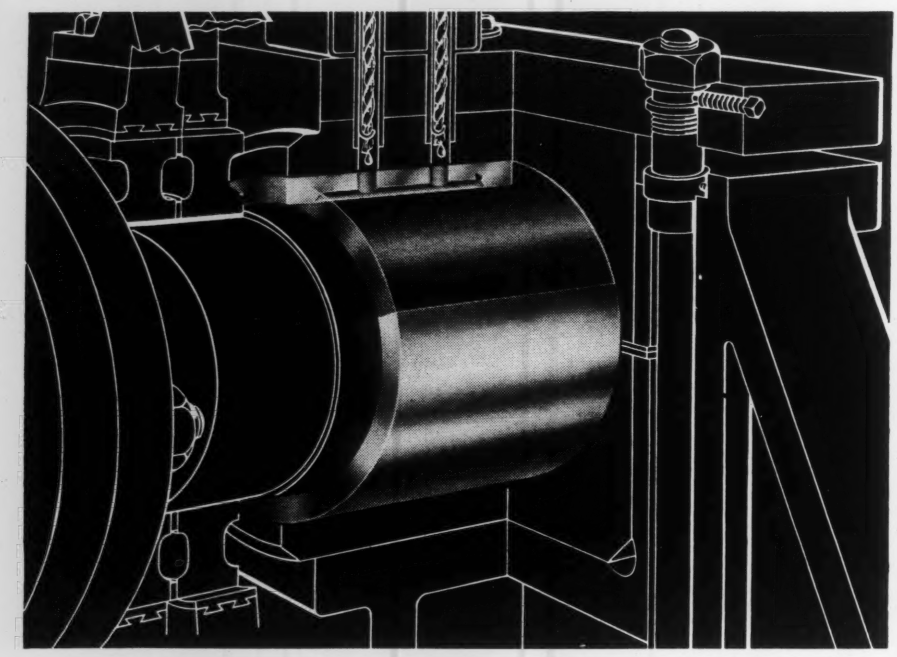

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Cost of replacement

Any bearing, regardless of type, may one day reach the point where it requires replacement. If this point is reached the replacement of a sleeve bearing is far less costly than the replacement of any other type of bearing.

Disassembly and removal of the original bearing, installation and reassembly with the new bearing are simpler, quicker and therefore less costly and the cost of the sleeve bearing itself is moderate compared to the cost of other types.

The user of equipment which you design and build will appreciate these advantages of a sleeve bearing.

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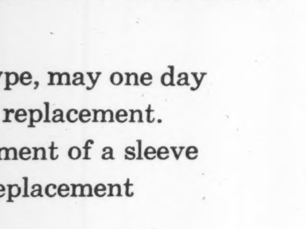

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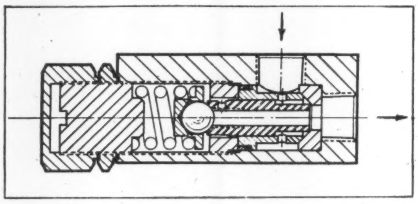
stat has single stud mounting for rapid heat transfer. A wide variety of terminal arrangements is available, and adjusting stems are made to specifications. Made by **Stevens Mfg. Co.,** 69 S. Walnut St., Mansfield, O.

For more data circle MD-84, Page 237

Piston Type Relief Valve

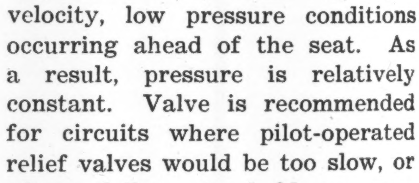
Differential piston-type relief valve is extremely quiet and has fast response to pressure surges. Pressure acts on annular area between outer diameter and reduced diameter of piston. Effective force of pressure is not reduced by high-velocity, low pressure conditions occurring ahead of the seat. As a result, pressure is relatively constant. Valve is recommended for circuits where pilot-operated relief valves would be too slow, or where failure to hold pressure would be dangerous. It is available in 1/4 and 3/8-in. sizes. Made by **Fluid Controls Inc.,** 1284 No. Center St., Mentor, O.



For more data circle MD-85, Page 237

Machinery Mountings

Heavy machinery can be installed and leveled in a matter of minutes, without bolting or shims, with 10,000-lb capacity LM7 Barrymounts. Permitting height



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Splash-proof flange mounting
world's most respected motor
Totally enclosed externally fan-cooled
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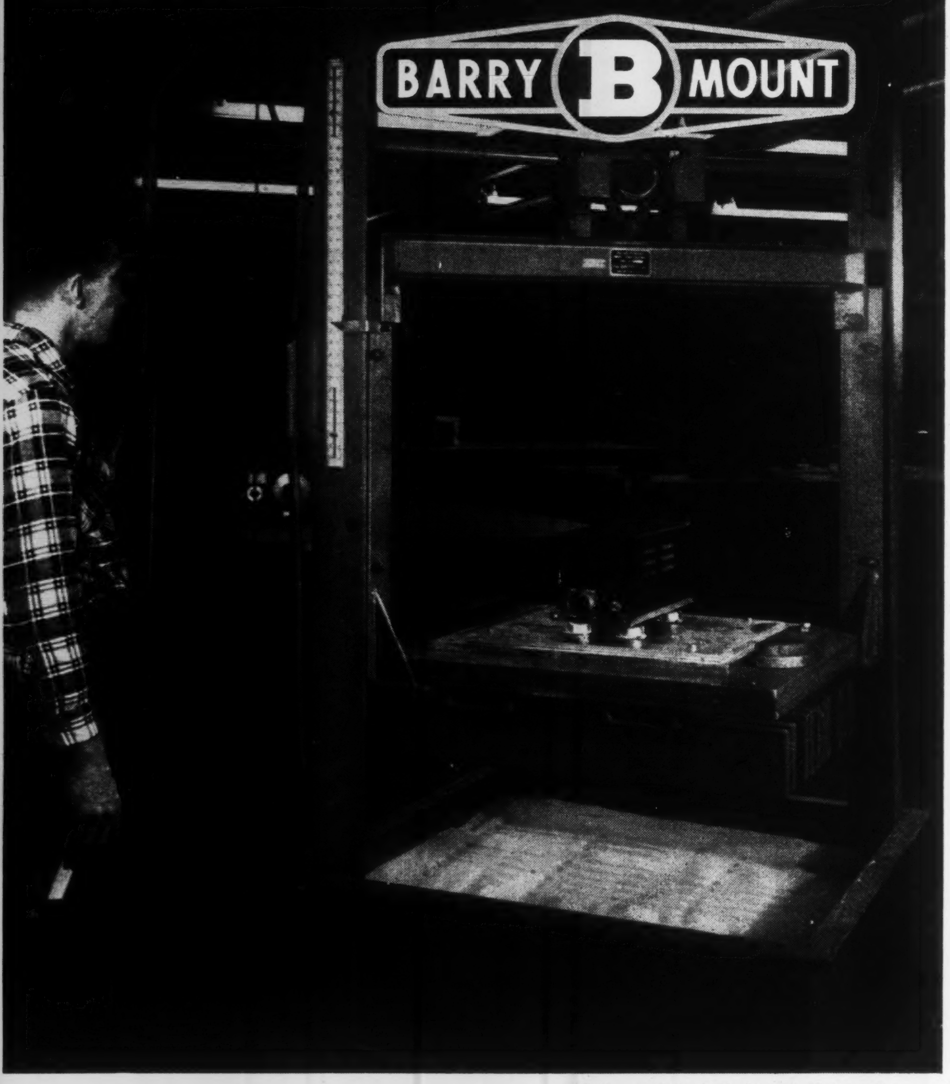
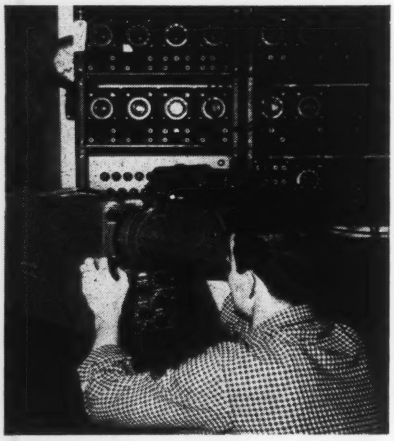


Photo courtesy Bell Aircraft Corporation

How to assure the operation of a pilotless bomber

One way — used by Bell Aircraft Corporation — is to subject every component to a multitude of tests so as to minimize possibility of failure. Barrymounts® that protect delicate electronic equipment, and Barry VD impact-shock machines that provide high accelerations for tests, play an important part in the production of the guided missiles that Bell Aircraft has designed and is manufacturing.

For assured protection of your electronic devices, we can furnish standard Barrymounts® or can develop and manufacture special units for your particular needs. And we can furnish shock-testing equipment for your use or we can conduct your tests in our shock and vibration laboratory. *Write for Bulletin BA-54.*



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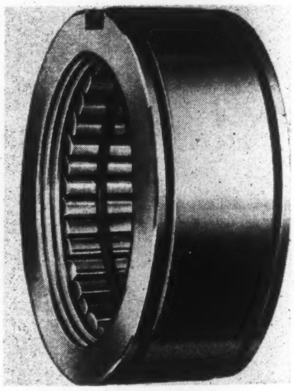
adjustments up to $\frac{1}{2}$-in., mounts lift machine foot to required height for leveling by simple turn of attaching bolt. They are engineered to isolate vibration and noise, and eliminate "walking" of machinery. Made by **Barry Corp.,** 700 Pleasant St., Watertown 72, Mass.

For more data circle MD-86, Page 237

Backstop Clutch

Series 50 backstop clutch is suitable for gear reducing applications where the backstop can be incorporated into a bearing bore and an existing shaft extension can be used for an inner race. Unit has full sprag complement, and the inner race is supplied by user. Outer diameter is basically the same as the outer diameter of a standard bearing. Diameter tolerance is held to insure proper fit (without pressing) into a continuation of the adjacent bearing bore. Torque capacities range from 170 to 3950 lb-in. Made by **Formsprag Co.,** 23601 Hoover Rd., Van Dyke, Mich.

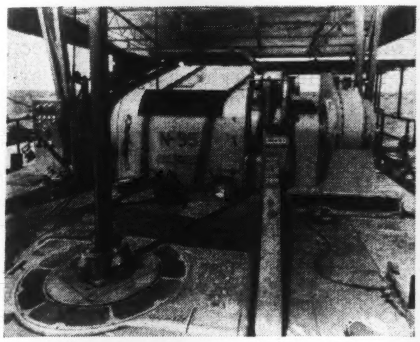


For more data circle MD-87, Page 237

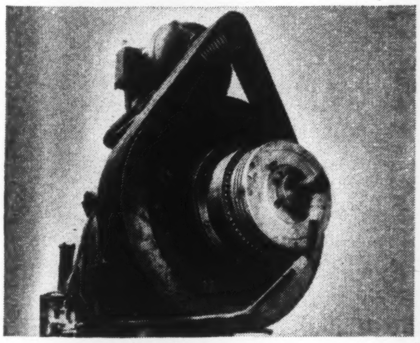
Small Counters

Micro Meter series of small diecast counters includes ratchet style, with either internal or external stops; ratchet rotary, direct drive and complete - revolution counters. All are available in three, four and five-digit capacity with base flange or window flange for panel mounting. Two direc-

Air-Actuated Clutches prove adaptability in variety of industries . . .



For greater efficiency and longer working life, the new Brewster N-95 Drawworks standardizes on Twin Disc Model PO as working clutches, with a 3-plate 30" on the low drum, 2-plate 30" on high drum, and 3-plate 24" as master clutch.

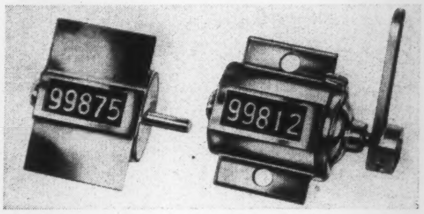


A Twin Disc Air-Actuated Clutch provides remote control and smooth engagements for this Ferracute 75-ton Press — plus higher capacity, less weight and lower inertia which permits operation speeds to be increased 100% on short strokes.

TWIN DISC
CLUTCHES AND HYDRAULIC DRIVES

TWIN DISC

TWIN DISC CLUTCH COMPANY, Racine, Wisconsin
Hydraulic Division, Rockford, Illinois

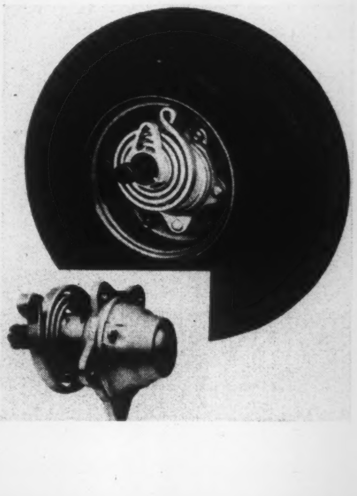


tions of rotation are provided, and the drive may be on the right or left side of the counter. Engraved figures are white against a black background, 11/64-in. high. Counters are sealed and require no lubrication. Speed range is from 500 to 1000 counts per minute. Made by **Durant Mfg. Co.,** 1933 N. Buffum St., Milwaukee 1, Wis.

For more data circle MD-88, Page 237

Axle Assembly

Suspension type Floating-Hub shock-absorption system has stub axle for transport trailers. It can mount pneumatic, semipneumatic or cushion type tires with conventional wheel mounting bolts. Stub is inserted into tubing or a clamping bracket, and the mounting plate is bolted to the wheel hub. Design and location of the load-carrying spring in relation to the suspension and wheel center permit instant deflection of the wheel toward the rear when it hits an obstacle or rough spot. This deflection is followed by immediate recovery to keep the impact from being transmitted to the vehicle. Wheel is balanced and rides on true centers on precision bearings which are sealed to retain lubricant and preclude



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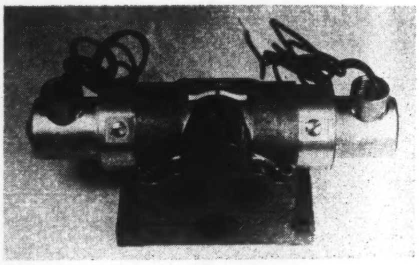
entrance of foreign matter. Installation or interchange is accomplished with a screwdriver and wrench. Recommended operational load rating of the assembly is 1000 lb. Units rated at 2000, 3000 and 4000 lb will be available. Made by **Bassick Co.,** Bridgeport 2, Conn.

For more data circle MD-89, Page 237

Four-Way Valves

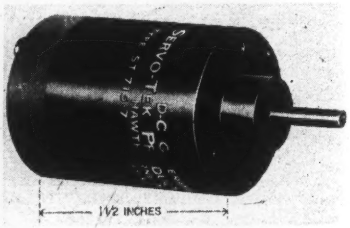
Only moving part in MV series four-way valves is the one-piece spool which carries the only moving seals employed. These are easily replaced standard O-rings. Suitable for air or hydraulic service to 200 psi, valves can be adapted to sub-base, manifold, panel, console or conventional piped installations. Attachments provide for operation by lever, palm button, foot pedal or treadle roller, cam, solenoid, pilot or remote bleeder button. Parts are standardized and interchangeable. Made by **Modernair Corp.,** 400 Preda St., San Leandro, Calif.



For more data circle MD-90, Page 237

Tachometer-Generators

Incorporating a permanent-magnet field assembly, this dc tachometer-generator is less than 1½ in. long and weighs under 3 oz. Used principally as a rate genera-



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The growth of western industry and its exacting requirements have brought to California Arwood's fourth investment casting plant. Here you'll find the advanced tooling, metallurgical, and testing facilities necessary to serve you with the highest quality of precision investment castings. Small, intricate, investment-cast parts require no machining . . . quantities of these parts can be cast in unmachinable metals . . . and several parts can often be cast into a single assembly. Applications are virtually unlimited.

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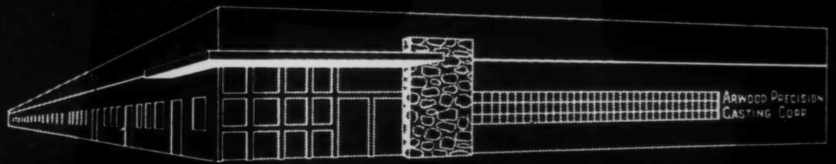
With the new California plant in full operation, Arwood's three eastern plants have been relieved of considerable overload. As a result, Arwood is able to extend more service to its customers throughout the nation.



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No place is distortion control more important than on heavy duty gears which are run almost continuously at full rating and subjected to extreme shock loads such as are encountered in rolling mill operations. BRAD FOOTE **DEEP CASE HARDENED** gears run true and distribute the load evenly across the full face and on the designed bearing surfaces of each tooth.

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In addition, BRAD FOOTE rigidly controls to set standards the depth of **DEEP CASE HARDENING** and the carbon content. The tooth surfaces are of maximum hardness for long life, but the carbon content is gradually diminished at successive depths below the surface until it blends to the metal of the core itself.

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Thus the cores of the teeth and the body of the gear remain ductile and shock-resistant while the teeth are given an increase in service life of over 50%.

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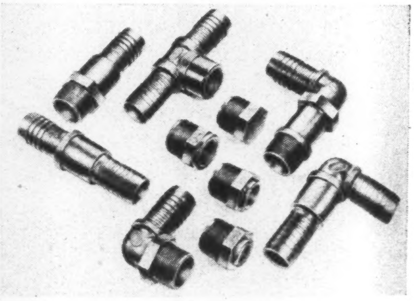
tor in a servo system, the unit can be combined with a standard 1000-ohm-per-volt voltmeter to make a direct-reading tachometer, or used as an under or over-speed indicator or speed synchronizing control. Output voltage is controlled to within 1 per cent of the same value for either direction of rotation. Models are available with output of 2.5 or 7 v per 1000 rpm. Flange mounting is standard, and a synchro type mount is available. Made by **Servo-Tek Products Co. Inc.,** 1086 Goffle Rd., Hawthorne, N. J.

For more data circle MD-91, Page 237

Plastic Pipe Fittings

Added to standard line of adapters, couplings, tees and ells, 27 special-purpose fittings for flexible plastic pipe are corrosion-resistant virgin polystyrene copolymer. Included are extra-length couplings, adapters and elbows; short and long adapter elbows; and insert reducing tees with female threads in the stem. Fittings have small secondary leak-sealing serrations in the clamping area. They have a hex where applicable for easy handling. Made by **Franklin Plastics Inc.,** Franklin, Pa.

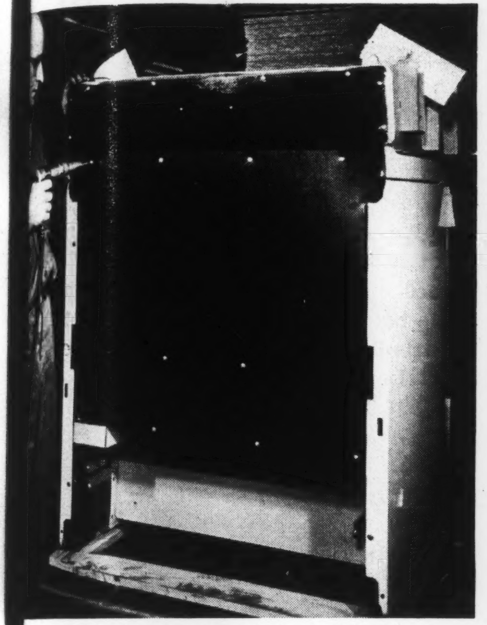


For more data circle MD-92, Page 237

Industrial Adhesive

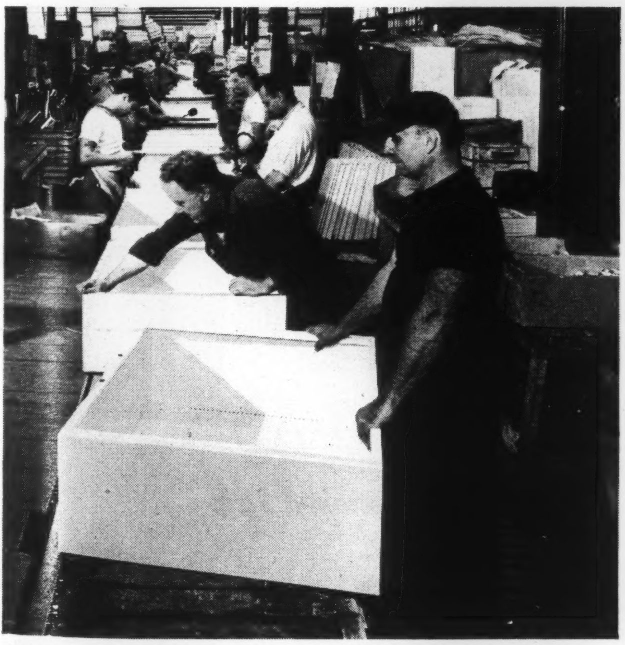
Neoprene adhesive F-1 spreads readily and can be applied with a spatula, brush or spray equipment. It does not require accelerators, catalysts or two-part mixing. Adhering to almost any type of surface, the material exhibits ex-

Users praise Phillips Cross-Recessed-Head Screws



TAPPAN RANGES are built to last for years. "Screws must remain tight over long periods of use," points out Paul N. Smith, Project Engineer. "I don't know of a single case where Phillips screws have failed us in this sense. We now use them exclusively. I can't say enough about their fastening qualities compared with the slotted type. Their greater contact area enables us to apply much greater torque without injury to employees." Ralph Stafford here fastens back panel.

FRONT PANEL OF A BRYANT MODEL 315 OIL FURNACE is assembled here by Ronald W. Eary. "All of our applications are metal-to-metal connections," states John Zonza, foreman of the General Assembly Department. "They must be set up extremely tight for rigid construction. With slotted screws, we had to use too much torque to secure a tight fit. This resulted in 'chewed' up heads, and damage to employees' hands. Phillips screws have eliminated this."



TRACY KITCHEN CABINETS use Phillips screws on their one movable part: the door hinge. "We have tested other type screws," says B. J. Krywick, general manager, "but decided on Phillips screws because they give us more ease of assembly, greater speed of assembly, more positive contact and driving power. They also eliminate slippage, give us less rejects and enable us to use production methods impossible with other type screws."

MANUFACTURERS OF PHILLIPS CROSS-RECESSED-HEAD SCREWS

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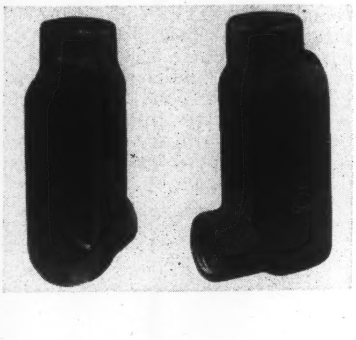
cellent adhesion to metals, structural materials, natural and synthetic rubbers, glass, paper, and many plastic materials including polyester-glass laminates, rigid vinyls and phenolic laminates. Only good contact pressure is necessary to insure a strong bond. Although not a vulcanizing type adhesive, it does cure on aging, strengthening the bond. Made by Adhesive Dept., **Carboline Co.,** 331 Thornton Ave., St., Louis 19, Mo.

For more data circle MD-93, Page 237

Conduit Fitting

OR series conduit fittings have oval covers and flat backs. Ferrous alloy castings have tapered machine-cut threads, and the large flat back area is easily drilled for secure mounting on vibrating machines. Large, smooth interiors facilitate wire pulling, and the rounded edges prevent wire damage. Covers have self-retaining screws. Made by **Pyle-National Co.,** 1334 N. Kostner Ave., Chicago 51, Ill.



For more data circle MD-94, Page 237

Terminal Strip

Right-angle terminal strip No. 3366 facilitates periphery assembly of printed or etched circuits by fast dip method of solder points. Strip has fifteen 0.040-in. diameter terminals along each side, and omission of certain terminals can be made to requirements. Nominal creep is 3/32-in. Pins are phosphor bronze with plating of gold over silver. Terminals extend through cards 1/16, ⅛, and ¼-in. thick. Strip mate-

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10 key features in a brilliant new design

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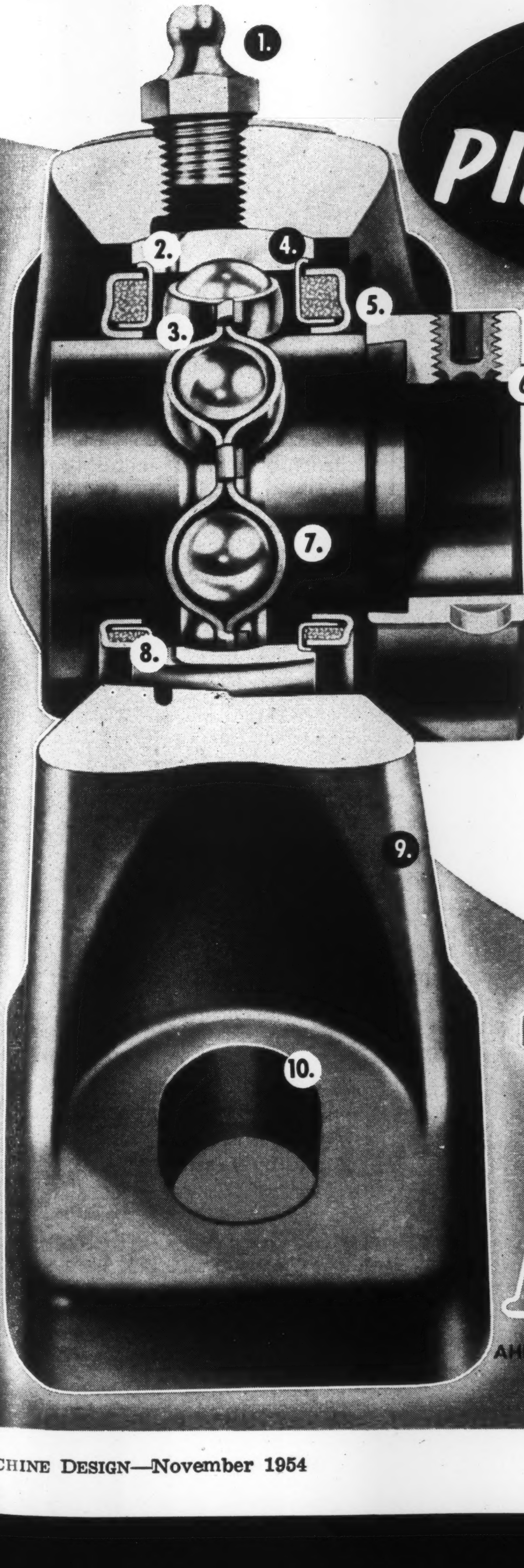

Good news for bearing users! The new SP combines all modern pillow block features to give you finer performance . . . longer life . . . greater economy!

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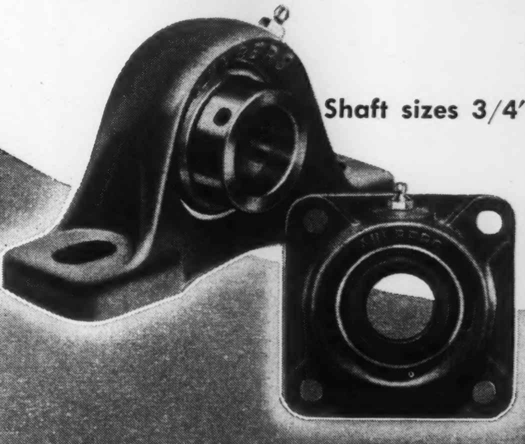

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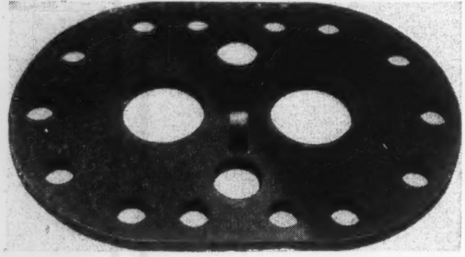

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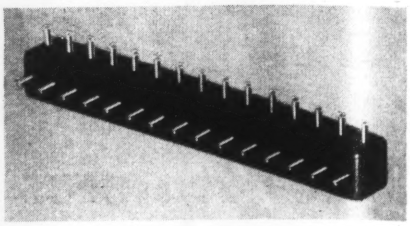
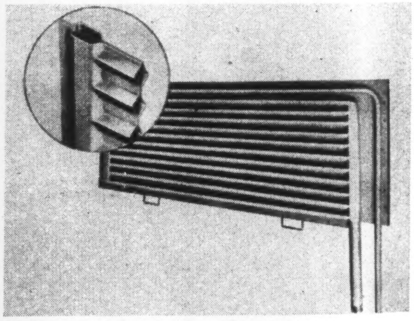


rial is standard 3700 green mineral filled phenolic, or can be obtained in mineral filled phenolic type MFE, diallyl phthalate MDG, or general purpose phenolic CFG. Made by **H. H. Buggie Inc.**, 726 Stanton St., Toledo 4, O.

For more data circle MD-95, Page 237

Heat Transfer Units

Plate-coil heat transfer units made of Ampco alloy, Carpenter 20 alloy, Hastelloy B and Hastelloy C can be used in pickling, hydrochloric acid installations, petroleum processing and other applications involving salt water, sulphuric acid and chromic acid.



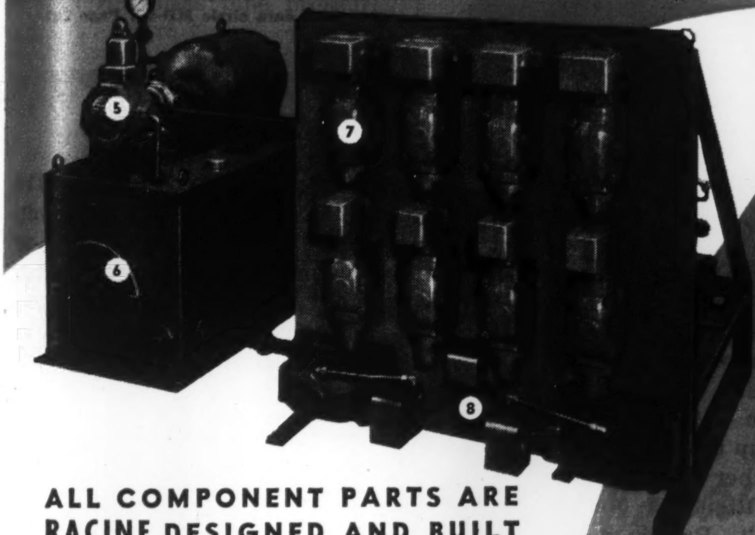
With previously made cold rolled steel, stainless steel and Monel units, heat transfer units will resist over 200 different corrosive liquids. Unit consists of two embossed metal sheets welded together to form channels for the passage of heat transfer media. Made by **Tranter Mfg. Inc.**, 510 E. Hazel St., Lansing 4, Mich.

For more data circle MD-96, Page 237

Patterned Metal

Available in stainless steel, aluminum, carbon steel, brass, copper and all other ferrous and non-

A Compact Hydraulic POWER HOUSE one of many built by Racine for you . . .



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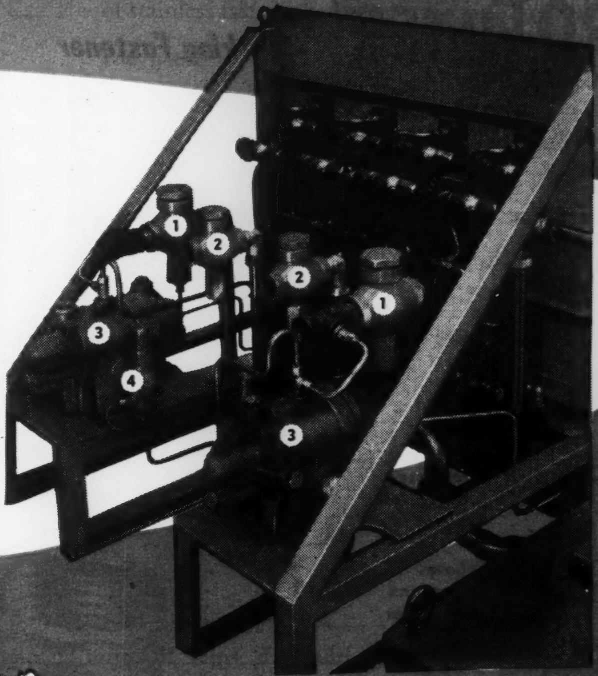

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2	**RACINE Free Flow and Throttling Check Valves**
3	**RACINE Pressure Boosters**
4	**RACINE Sequence Valve**
5	**RACINE Variable Volume Pump**
6	**RACINE Oil Reservoir**
7	**RACINE Solenoid Controlled, Pilot Operated 4-way Valve**
8	**RACINE Solenoid Operated 2-way Valve**

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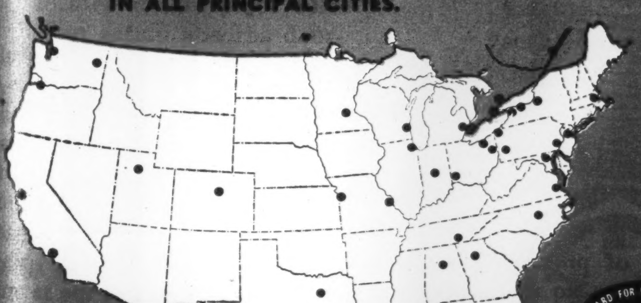

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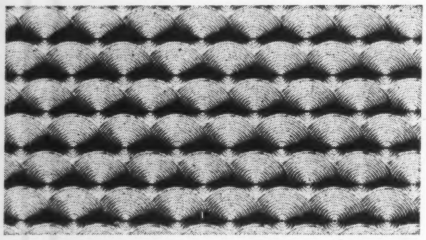
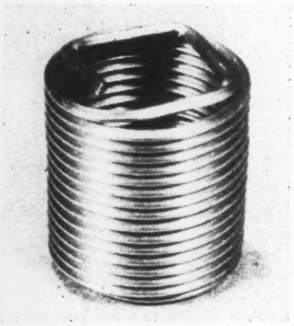
ferrous metals, 1-ET decorative metal can be fabricated by conventional techniques and machines. Pattern, with maximum depth of 0.025-in., provides a surface which resists marring, hides scratches and fingerprints and reduces glare. Material is available in widths up to 7 in. in sheet, strip or coil, either solid or perforated. Made by **Rigidized Metals Corp.**, 693 Ohio St., Buffalo 3, N. Y.



For more data circle MD-97, Page 237

Locking Fastener

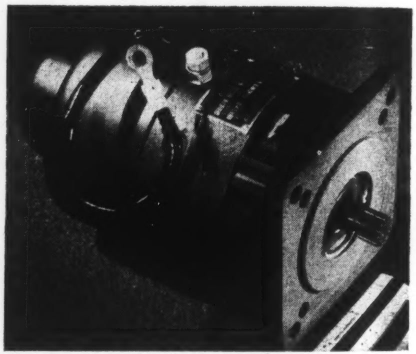
Screw-lock insert provides strong, permanent threads in soft materials such as aluminum, magnesium and plastics, as well as steel. It is made of precision-formed 18-8 stainless steel wire having an ultimate tensile strength of about 200,000 psi. Insert has a constricting area in the bottom coil which grips the screw. It automatically locks the screw to keep it from vibrating and locks itself into the parent material without the use of pins, rings or staking. It requires no more boss material or wall thickness than a conventional tapped thread. Screws in the screw-lock inserts do not require locknuts. Insert is dimensionally stable over a wide temperature range and resists wear, corrosion, galling and seizing. Made by **Heli-Coil Corp.**, Shelter Rock Rd., Danbury, Conn.



For more data circle MD-98, Page 237

Speed-Regulated Motor

Providing starting torque of 110 lb-in. in a continuous-duty unit, type SC-5 motor produces 1 hp at 12,000 rpm, regulated to ±6 per cent in speed variation. It draws 45 amp, operating over dc voltage range from 25 to 29.5, and regulates over a load variation of 2/3 to 1 hp. Motor withstands adverse temperature, humidity and pressure conditions. By-pass capacitors built in at armature and governor brushes minimize radio interference during operation. Motor is avilable with various types of output shafts. Made by **Dalmotor Co.**, 1347 Clay St., Santa Clara, Calif.



For more data circle MD-99, Page 237

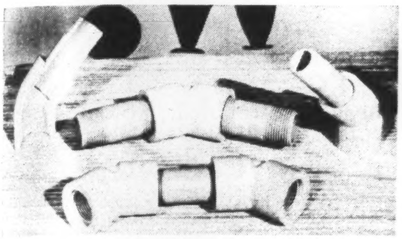
Plastic Pipe

Lightweight, odorless, tasteless and noncontaminating, Dur-Ace rigid plastic pipe has good resistance to impact and all inorganic acids and alkalis except for a few strong acids. Strength, rigidity and chemical resistance are maintained over temperature range from −40 to 170 F. Pipe is made in sizes from ½ to 2 in. in 20-ft lengths and in two wall thicknesses. Maximum working pres-

(*Continued on Page* 279)

(Continued from Page 270)

sures at 70 F for heavy wall pipe range from 300 psi for ½-in. pipe to 150 psi for 2-in. pipe. Standard wall thickness pipe pressures

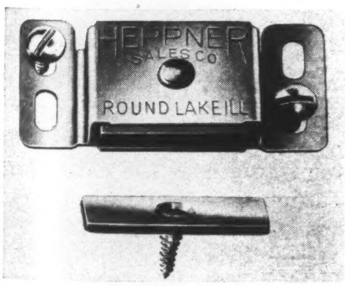


are one-half those of heavy wall pipe. Threading is by standard pipe threading tools or machines. Pipe can be bent if heated first. Made by **American Hard Rubber Co.,** 93 Worth St., New York 13, N. Y.

For more data circle MD-100, Page 237

Magnetic Door Latch

With a holding force of 10 lb, 320 times magnet's ½-oz weight, this magnetic door latch is practical for wood or metal doors.



Self-aligning action is accomplished by special tack which accurately locates striker plate hole. Pivot-cushion action absorbs door-slamming shock, preventing damage to latch. Size of latch is 2⅛ x ½-in. Available from **Heppner Sales Co.,** Round Lake, Ill.

For more data circle MD-101, Page 237

Precision Potentiometer

Subminiature, wire-wound precision potentiometer is ½-in. in diameter and weighs ¼-oz. It has low dielectric constant and power

STAINLESS STEEL FASTENINGS
by Anti-Corrosive

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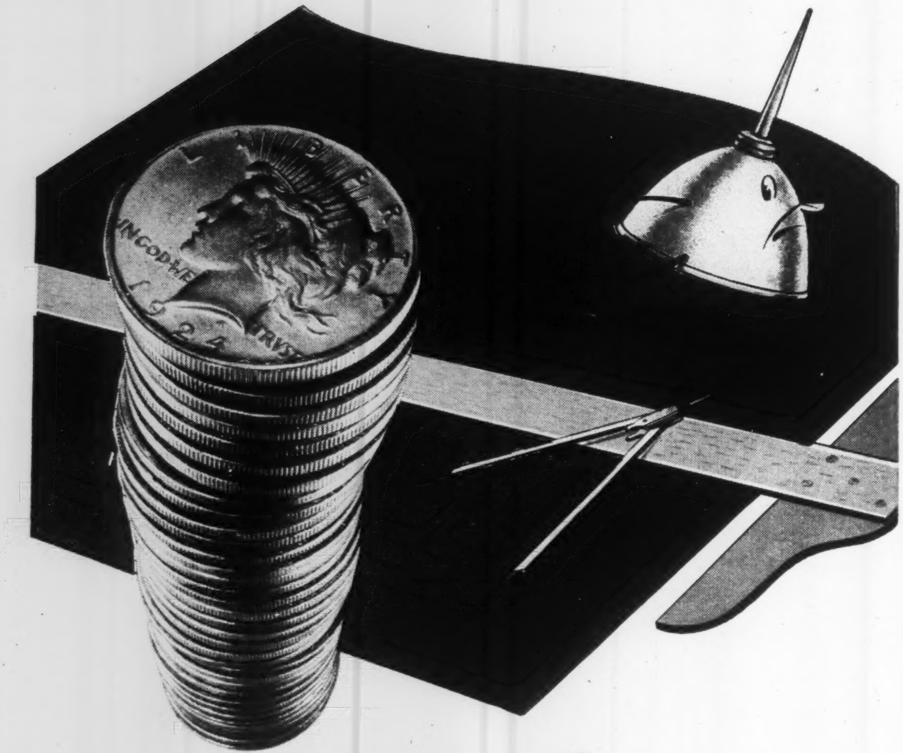

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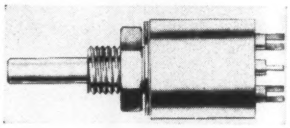
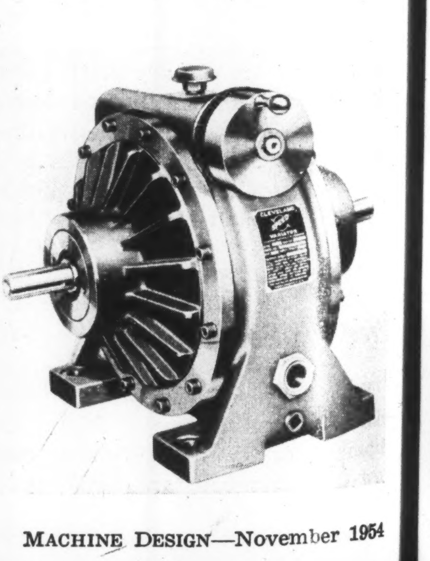
factor. Power rating is 2 w for 60 C rise. Resistance range is 200 to 50,000 ohms, held to a tolerance of ±2 per cent or closer. Standard independent linearity is ±0.3 per cent, and lower values can be had. Unit operates in temperatures range of −55 to 125 C. Maximum static torque of 0.035-oz-in. at 20 C can be even lower if required. Standard potentiometer has gold or silver plated solder terminals. It is sealed against foreign matter and is resistant to corrosion as well as shock and vibration. Units can be ganged on one shaft with terminal boards on side of cases. Made by **Ace Electronics Associates,** Potentiometer Div., 125-129 Rogers Ave., Somerville 44, Mass.



For more data circle MD-102, Page 237

Variable-Speed Transmission

Speed Variator utilizes the rolling action of a series of balls to provide infinite speed variation from one-third to three times the input speed, or a total range of 9:1. Transmission operates at full power rating over the entire range of output speeds. Power is transmitted from the input shaft to the input drive disk, which is in pressure contact with the balls. A similar contact between the



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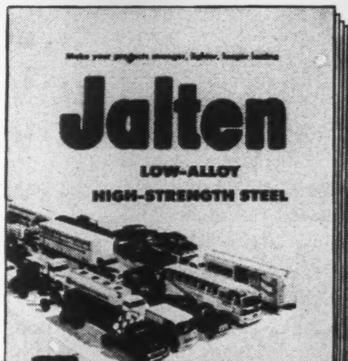

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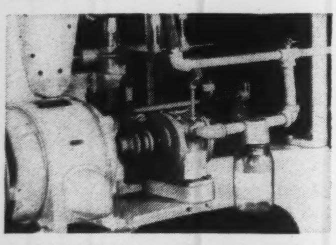
Models 1065 and 2065 Rotary Compressors are used on York-Shipley "Steam-Pak" Boilers to insure the maximum in fuel oil atomization and combustion.



Model 1550 Vacuum Pump is used on Stokes & Smith paper box wrapping machine to automatically pick up the sheets of covering paper.

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...up to 30 p.s.i.

...1/2 to 24 c.f.m.

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(TO 4 H.P.) (TO 30 LBS.) (TO 28 INCHES)

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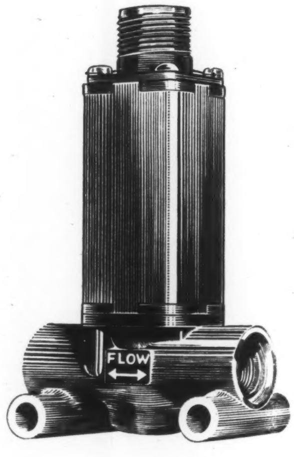
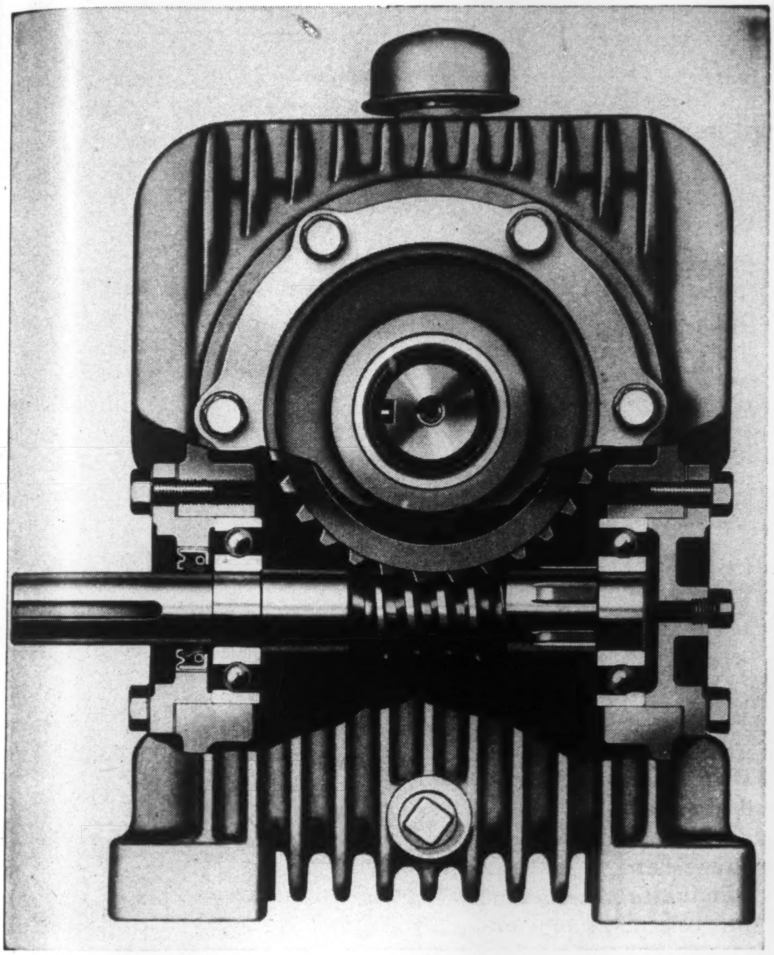
drive balls and the output drive disk transmits power to the output shaft. Disks are not connected directly to the drive shafts, but are driven through roller and cam pressure mechanisms, which cause the drive disk to press against the balls with a force proportional to the applied torque. Balls are positioned both radially and axially by the three points of contact provided by the free-floating outer ring and the two drive disks. Relative speeds of the shafts are adjusted by the angular positioning of the axles about which the balls rotate. Speed adjusting mechanism is controlled by a worm and gear, which can be operated either manually or by a variety of remote control devices. Variator is built in sizes ranging from ½ to 10 hp. Made by **Cleveland Worm & Gear Co.,** 3249-59 E. 80th St., Cleveland 4, O.

For more data circle MD-103, Page 237

Solenoid Valve

Self-lapping, self-cleaning Valcor U-3900 solenoid shutoff valve has straight-through flow, gate type floating seal and an improved solenoid coil which withstands shock, vibration and the elements. Valve has 100 per cent efficient seal in both directions and is lightweight in relation to capacity. It operates on 18 to 30 v dc at maximum pressure of 100 psi. Current drain is ½-amp at 24 v dc. Valve is offered in range





MORE HP PER POUND

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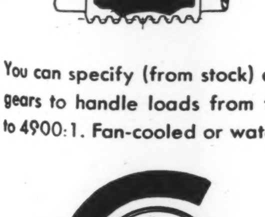
. . . it belongs in every driven product

You're looking at the "innards" of the most efficient worm geared speed reducer available today. It's Cone-Drive Gear's exclusive double-enveloping worm gear design, which means more load-carrying capacity, size for size, than any other type of right-angle speed reducer.



This simple design, with the gear and worm literally "wrapped" around each other, means a space and weight savings that often makes the difference between a compact, efficient product and just another machine.

You can specify (from stock) any one of 190,000 standard models of Cone-Drive gears to handle loads from fractional to 800 hp. You can have ratios from 5:1 to 4900:1. Fan-cooled or water-cooled models available if you should need them.

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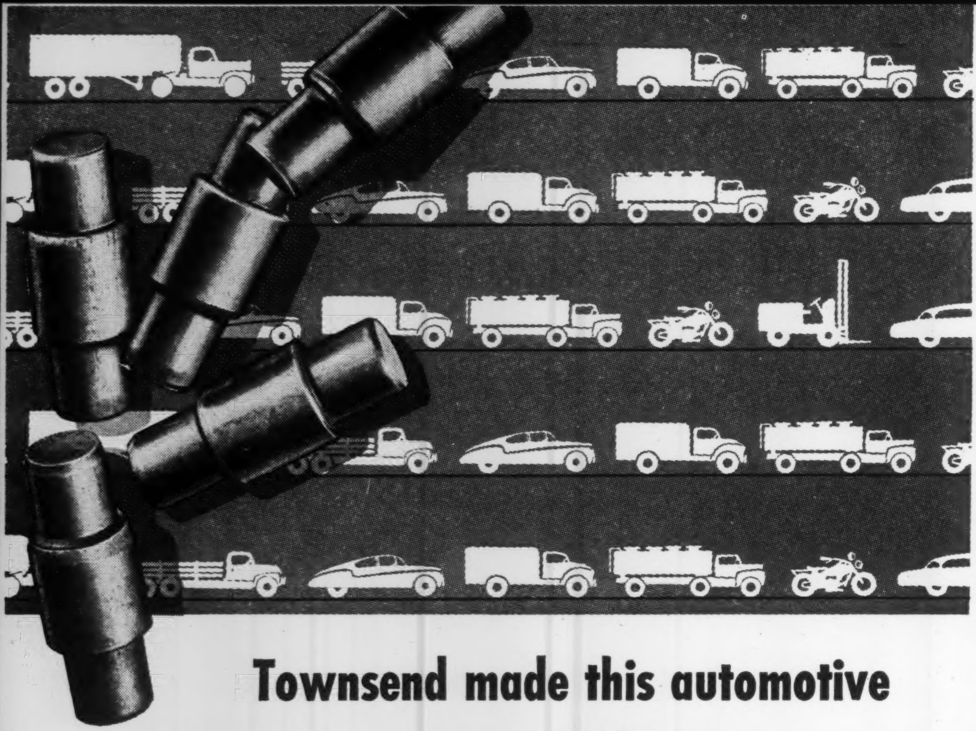

Townsend made this automotive part at a savings of $18,000 per year

Big savings turn up in unexpected places when you examine the cost of producing small parts and fasteners. That's what happened when a Townsend engineer suggested that this small spacer stud could be produced by the Townsend method of cold-forming at one-third the cost of the former method. Result—a cool $18,000 clipped from production costs and a tougher, stronger part.

This is possible because the Townsend method is fast. And all the raw material went into the part, none was cut away as scrap. As a result, more pieces per pound of metal were produced, resulting in additional economy.

Townsend parts have high resistance to shock and fatigue because cold-forming increases tensile strength. The flow lines of the metal follow the contours of the piece instead of remaining in a single plane, as with machined parts. Cold-forming strengthens the threads and eliminates stock notching. Close size tolerances and excellent surface finish are characteristic of Townsend parts.

As "The Fastening Authority," Townsend produces 60-million pieces daily—regularly makes more than 10,000 special and standard fasteners and parts. With this capacity and the experience of 138 years of metal working to draw upon, Townsend engineers will help you reduce your material and assembly costs. Ask to have one of them call. For more information use the coupon below or write for illustrated bulletin.

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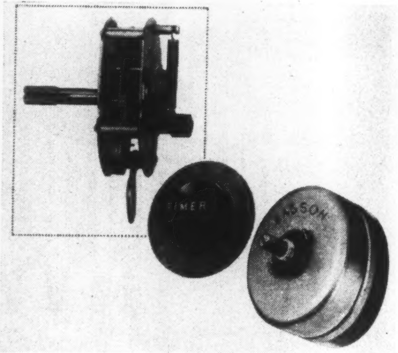
of port sizes in either normally open or normally closed types. Made by **Valcor Engineering Corp.,** Carnegie Ave., Kenilworth, N. J.

For more data circle MD-104, Page 237

Precision Timing Switch

Center stud mounting of this compact, precision bell timer switch facilitates installation. Switch operates at high ambient temperature. Friction clutch allows setting and resetting at will for any period up to 2 hours.

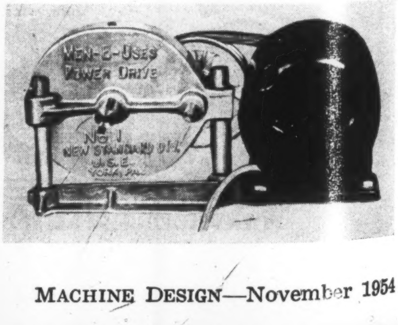


Clear, single stroke bell warns of automatic shut-off at end of preset period. Switch is rated 125 v, 13 amps and has Underwriters' approval. It measures $2\frac{1}{2}$-in. diameter by $2\frac{5}{8}$ in. Made by **Kasson Die & Motor Corp.,** 32-14 Northern Blvd., Long Island City 1, N. Y.

For more data circle MD-105, Page 237

Speed Reducer

Lightweight and easily adaptable to all forms of driving equipment, No. 1 Men-E-Uses power drive has a range of 20 to 750 rpm when used with motor of $\frac{1}{2}$-hp or less. Model No. 2 is designed primarily for heavy duty



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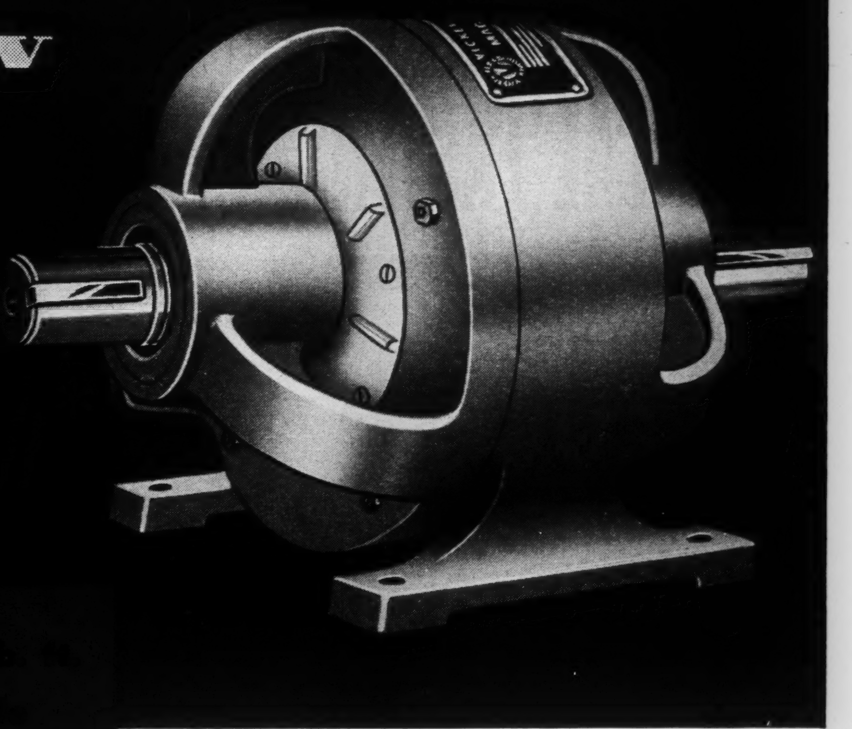

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models available

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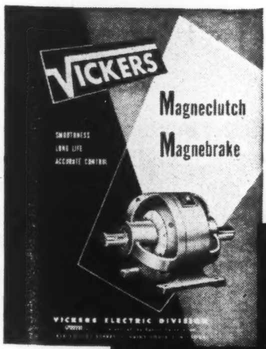
Vickers Magneclutch offers you these outstanding... advantages*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SMOOTHNESS
LONG LIFE
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VICKERS ELECTRIC DIVISION

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No grab or chatter

LONG LIFE

No wear on torque transmitting surfaces

TORQUE AT ZERO SLIP

Torque transmitted 100% without mechanical lockup

TORQUE LIMITING

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SMALL CONTROL POWER

EASILY ADAPTED TO REMOTE CONTROL

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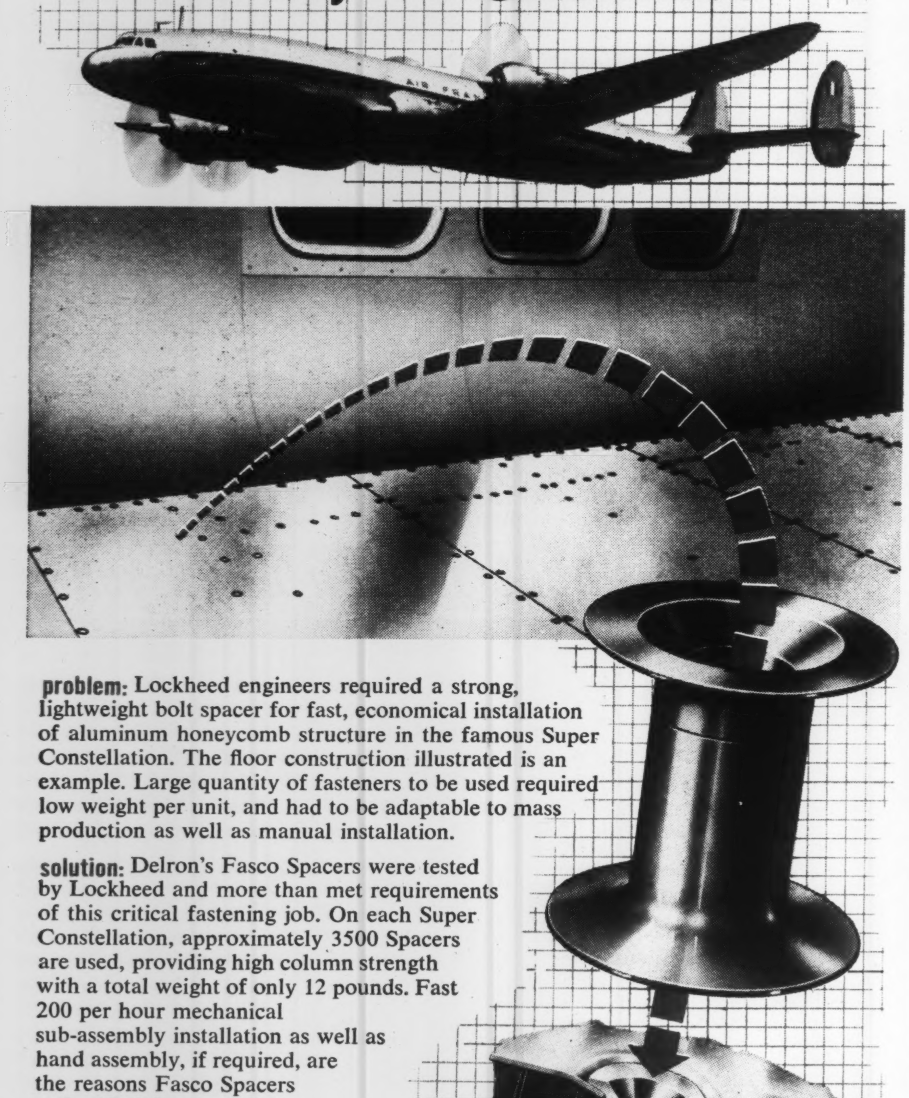
CRITICAL FASTENING PROBLEM
solved by Delron



problem: Lockheed engineers required a strong, lightweight bolt spacer for fast, economical installation of aluminum honeycomb structure in the famous Super Constellation. The floor construction illustrated is an example. Large quantity of fasteners to be used required low weight per unit, and had to be adaptable to mass production as well as manual installation.

solution: Delron's Fasco Spacers were tested by Lockheed and more than met requirements of this critical fastening job. On each Super Constellation, approximately 3500 Spacers are used, providing high column strength with a total weight of only 12 pounds. Fast 200 per hour mechanical sub-assembly installation as well as hand assembly, if required, are the reasons Fasco Spacers make ideal fasteners for honeycomb type structure.

This is another example of Delron's long service and design experience at work—solving critical fastening problems!

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☐ Sandwich structure fastening
☐ Fasteners to 1200°F. operation
☐ Fasteners to 1600°F. operation

Name______________________

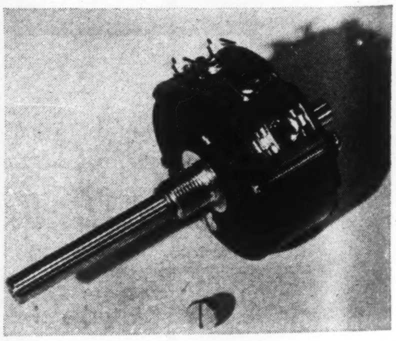
THE DELRON COMPANY, INC.
5224 Southern Avenue, South Gate, California

and can be used with ¼ to 2 hp motors to permit speed reduction ranging from 1 to 150 rpm. Speed is determined by size of pulley used. Model No. 1 has adjustable motor base and provision for mounting motor on either side. Model No. 2 has adjustable aluminum rails for mounting the motor on one of three sides. Both units are housed in aluminum gear cases. All bearings are self-oiling internally. Made by New Standard Div., **U. S. Expansion Bolt Co.,** York, Pa.

For more data circle MD-106, Page 237

Precision Potentiometer

Available in resistance ranges from 50 to 100,000 ohms in 10 standard increments, series 42-900 precision potentiometer is adaptable for prototypes, laboratory testing and similar uses. It has gold plated bushings, terminals and screws; anodized aluminum front and rear plates; adjustment for limited or continuous rotation and center tap. Power rating is 3 w. Made by **Clarostat Mfg. Co., Inc.,** Dover, N. H.

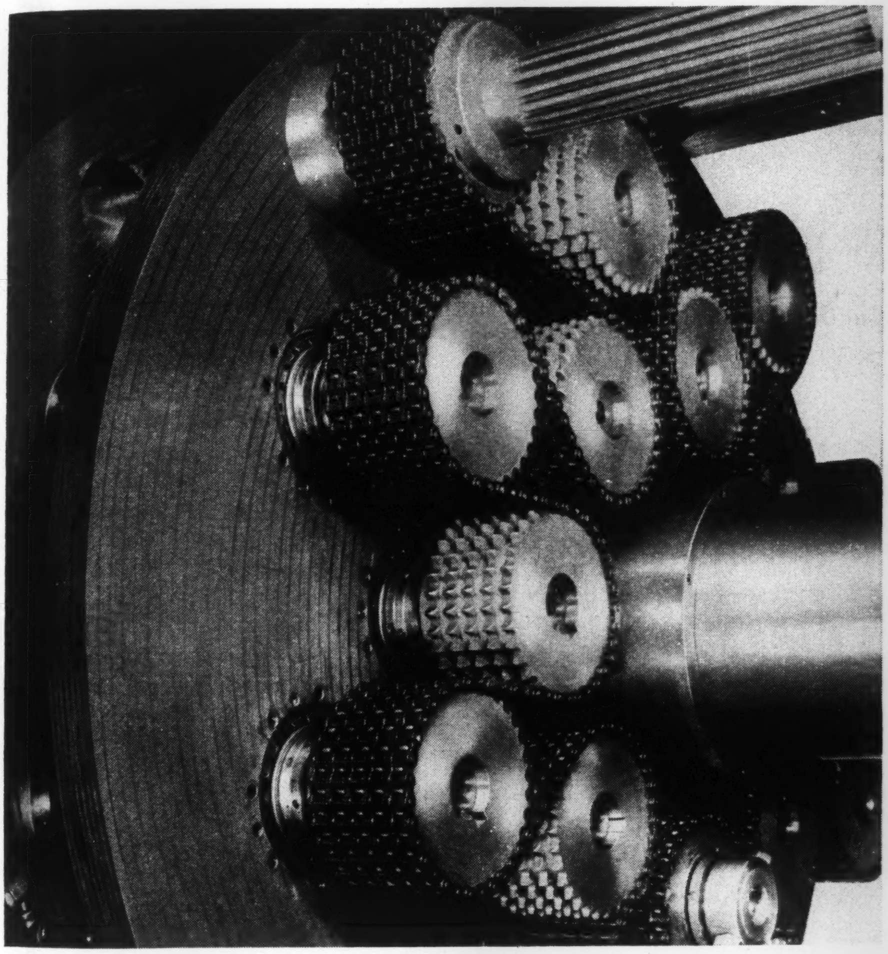


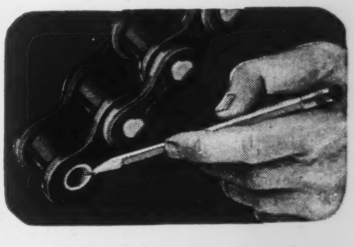
For more data circle MD-107, Page 237

Flow Regulator

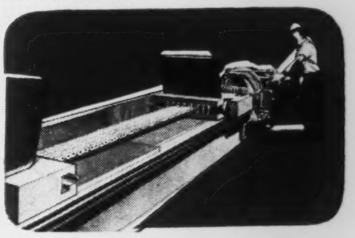
Constant rate of flow can be maintained by series 1801 flow regulator, regardless of variation in pressure or back pressure, while simultaneously by-passing excess pump output at working pressure. Operating pressure rating is 3000 psi. Unit is designed for use in power steering systems, fluid motors or any hydraulic system

In roller chain...EXTRAS* like these give you extra reliability

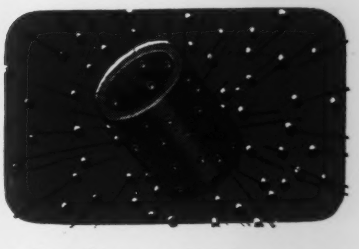




LOCK-TYPE BUSHINGS (applied on a range of sizes) end a common cause of stiff chain.



PRE-STRESSING of multiple width chain provides uniform load distribution.



SHOT-PEENED ROLLERS have greater fatigue life, added ability to withstand impact.

* And you pay no premium for these LINK-BELT extras

THERE'S more to roller chain than just the parts you see. *Much more!* It's the hidden extras—standard on Link-Belt Precision Steel Roller Chain—that add up to better performance, longer life and greater dependability for your machines.

Check the three extras shown above. Then choose from the broad range of Link-Belt roller chains and sprockets: Single or multiple widths, ¼″ through 3″ pitch. Double pitch, 1″ through 3″.

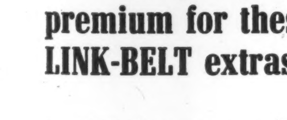
There's full ordering and application information in 148-page Data Book 2457. Ask your Link-Belt office for a copy today. Link-Belt's complete line of drive and conveying chains includes silent chain drives . . . all sizes and types of cast, combination, forged and fabricated steel chain.

LINK-BELT

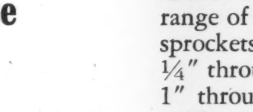
CHAINS and SPROCKETS

LINK-BELT COMPANY: Executive Offices, 307 N. Michigan Ave., Chicago 1. To Serve Industry There Are Link-Belt Plants and Sales Offices in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World. 13,644

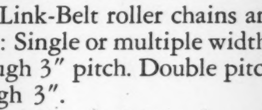
No one chain serves every purpose . . . get the RIGHT one from Link-Belt's complete line



Silent Chain for high speed drives from fractional to thousands of hp. Available in wide range of pitches and widths in middle guide, duplex, non-flange and side flange types.



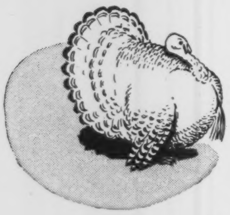
LXS Steel Chains, with offset or straight sidebars, are made to close tolerances. Ideal for rugged drives, conveyors.



Detachable Link-Belt chains, available in steel, malleable or Promal, for light-strength drives and conveyors.

S-815 Flat-Top Chain—easy to detach and keep clean — one of complete line for carrying bottles, cans, cartons, cases, etc.

Complete line of single and multiple width cut tooth sprockets as well as a wide range of cast tooth sprockets.



Everyone recognizes this
as a sign of Thanksgiving . . .
And smart gear users know
this CINTI is the sign of
the best in custom made gears.

May We Send You Our Brochure?

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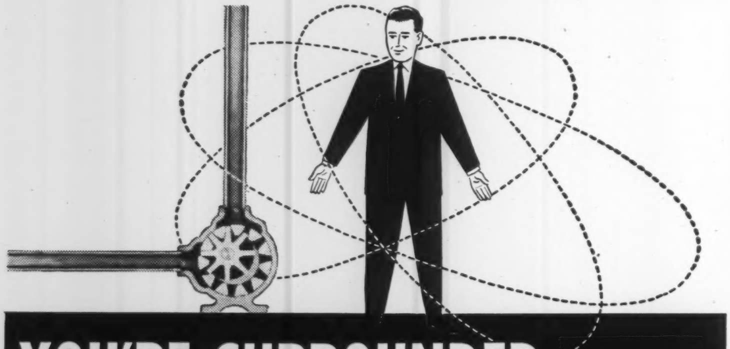
THE CINCINNATI GEAR CO. • CINCINNATI 27, OHIO



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They are everywhere, all around you. The newborn baby starts a life-long series of benefits from Viking pumps. Milk, foods, plastics, soaps, tooth paste, medicines, rubber, paint, gasoline, oils, fuels, fertilizers, asphalt and a host of others . . . all are Viking-pumped.

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And so throughout your life, Vikings' influence is everywhere . . . world-wide. For information, send for bulletin 55SH.

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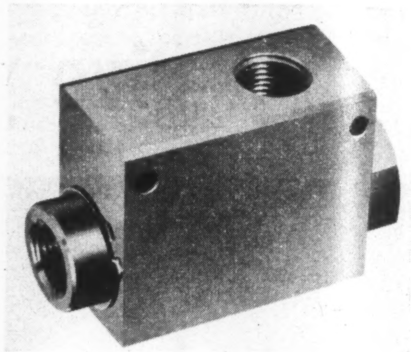
VIKING PUMP COMPANY
CEDAR FALLS, IOWA

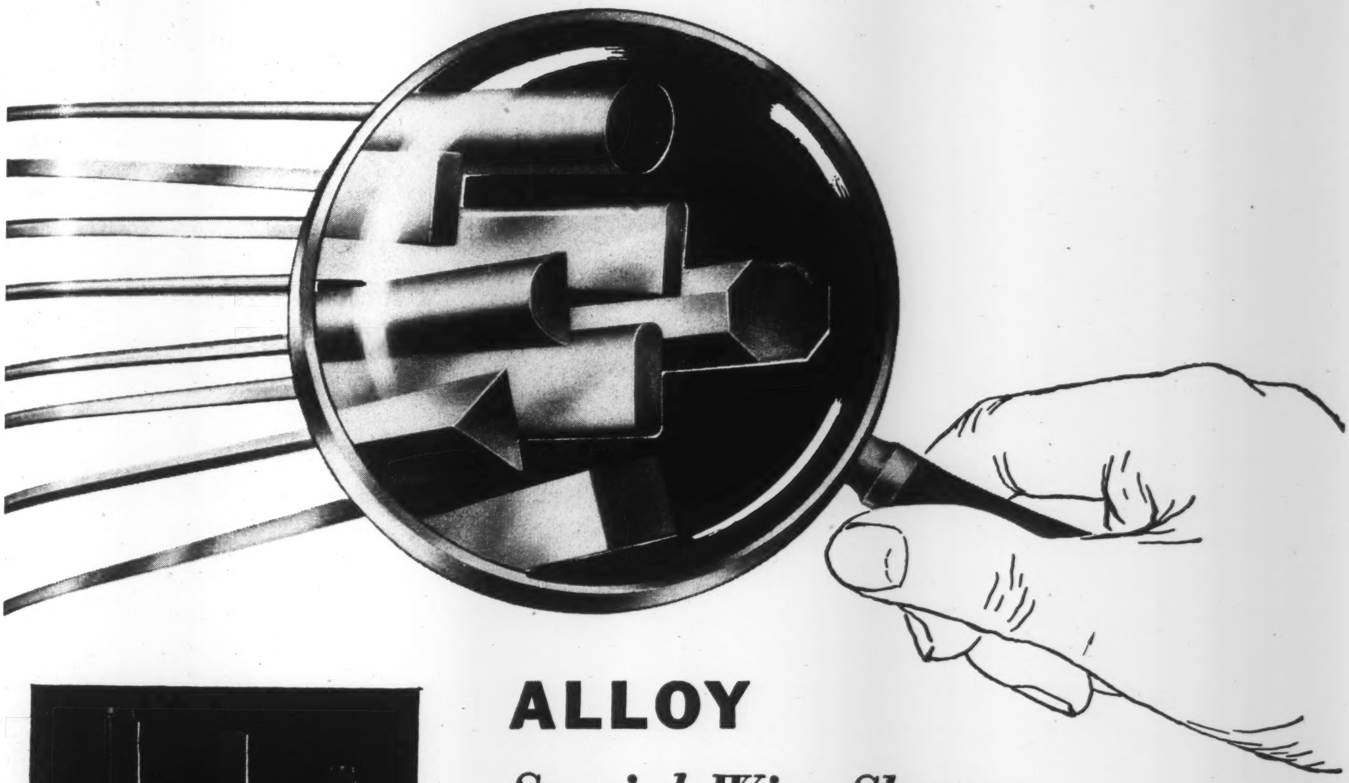


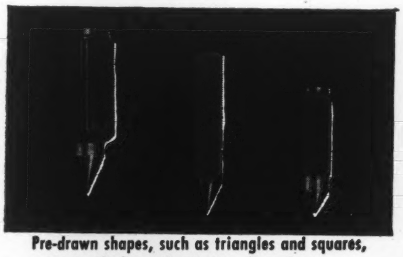
where constant flow is required in the presence of varying pump output. Regulator is made in $\frac{3}{8}$ and $\frac{1}{2}$-in. sizes with minimum and maximum controlled flows of 0.3 to 6 and 1 to 12 gpm, respectively, and minimum and maximum by-pass flows of 0 to 12 and 0 to 20 gpm, respectively. It has aluminum body and piston, steel sleeve and stainless steel precision calibrated spring. Stainless steel or bronze internal retaining rings are available for use with mildly corrosive fluids. Made by **Waterman Engineering Co.,** 725 Custer Ave., Evanston, Ill.

For more data circle MD-108, Page 237

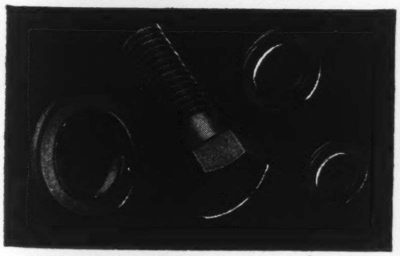
Motor-Starting Relay

Type ARR-1 motor starting relay is designed for single-phase, capacitor-start and capacitor-start, capacitor-run fractional or integral horsepower motors. It is applicable where adverse atmospheric conditions exist or where it is desired to have remote control incorporated into an explosion-proof case. Relay coil is wired across the starting winding of a single-phase motor. Relay is

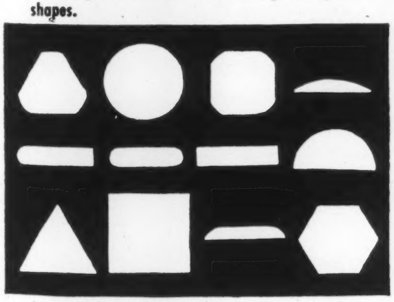




Pre-drawn shapes, such as triangles and squares, are naturals for carburetor needle valves.



Hex-head bolts and flat-wire lock washers take advantage of the material savings of special shapes.



Some of the special shapes now in production. Others can be developed to meet your needs.

ALLOY
Special Wire Shapes
CUT COSTS
Improve Product Performance

Alloy Special Wire Shapes eliminate costly machining time and cut metal waste. No need to start with round wire and then machine half of it away to get the shape you want. Alloy Metal Wire Division is ready to supply you with Stainless and Nickel Alloy wire in just about any special shape you may require. Some of the standard shapes available are shown here. We will be more than willing to work with you in the development of any other shape.

Drawn Alloy Wire Shapes provide other advantages in addition to reduced costs. Product quality and performance are also improved. The drawn wire insures uniformity of cross-section and a smooth, flaw-free surface.

For more details on Alloy Special Wire Shapes or for information on Stainless, Nickel Alloy or Electrical Resistance Wire, Rod and Strip, drop us a line. We are happy to be of service to you.

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of Pittsburgh
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1

The STANDARD

Durakool's
Deluxe Mercury Switch

LOW IN COST

This steel hydrogen filled mercury switch is recognized for its sensational ability to do the job at hand. Trouble free, dependable and low in cost.

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Hook Up With Servoboard and Speed Up Your Set-Ups

Whatever you're assembling—servo system, computer or regulator—the Servoboard speeds up the job by providing means for quickly synthesizing the electro-mechanical parts of the control system. Complete set includes gears, shafts, bearings, hangers and mounting plates, all precision made for rapid coupling with necessary motors, tachometers, synchros, potentiometers and amplifiers.

SERVOBIRD

Servoboard Model 1110A Experimental Mechanical Component Group

For detailed information Write Dept. MD-11

SERVO CORPORATION OF AMERICA
New Hyde Park, New York

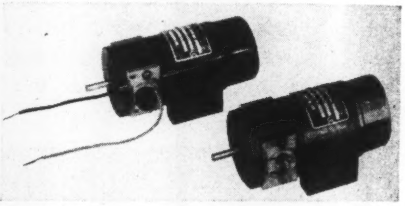
SC 121

available in ratings up to 5 hp, 115/230 v. Made by Appliance Control Dept., **General Electric Co**., Schenectady 5, N. Y.

For more data circle MD-109, Page 237

Tachometer-Generator

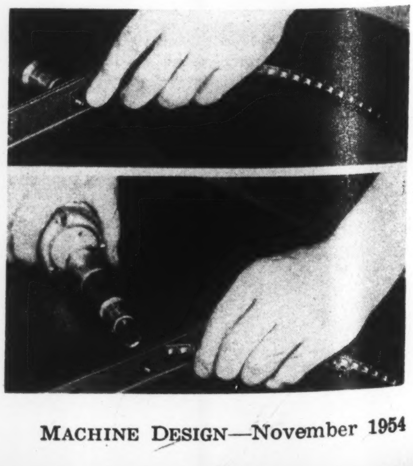
Measuring 3-11/16 in. long by 1¾ in. diameter and weighing under 20 oz, series of compact direct current motors and tachometer-generators are of the permanent magnet type. As continuous duty motors from 1/30 to 1/100-hp they operate on voltages from 6 to 27.5 and at speeds from 3000 to 9000 rpm. As tachometer-generators their outputs are from 0.46 to 2.4 v dc per 100 rpm up to 9000 rpm. Made by **Instrument Motors**, P. O. Box 5, Stamford, Conn.



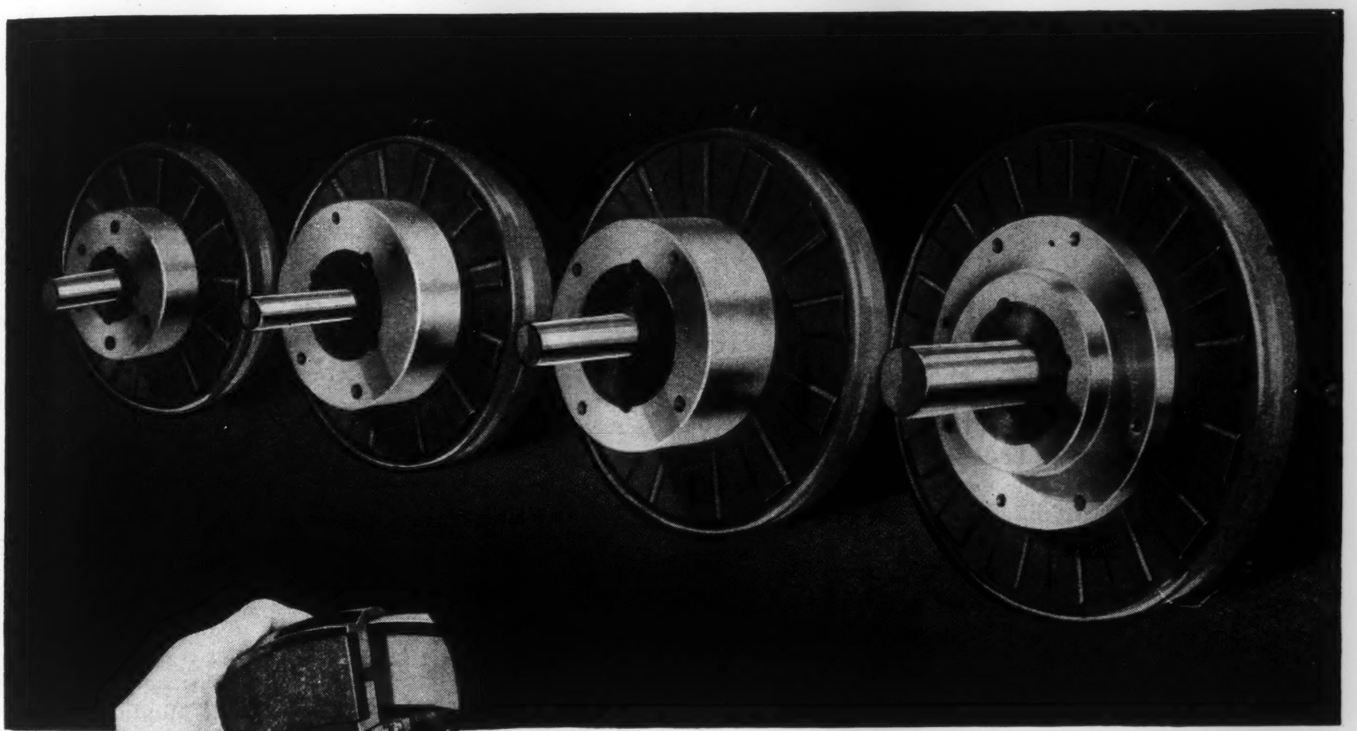
For more data circle MD-110, Page 237

Spring Tension Fasteners

Tandem-Type Speed Nuts are interchangeable for No. 6-8-10 and 14Z screws, as well as size 10-24, for which they were made originally. Fasteners are produced in coil or strip form with a partial shear between each nut. In as-



WARNER ANNOUNCES HIGH-TORQUE REPLACEABLE-FACE ELECTRIC BRAKES



New replaceable facing extends service life!

Now! All the advantages of *electro-magnetic control*—push-button or automatic—plus longer service life, lower replacement cost, and greater design flexibility are yours for high-torque machine drives. Warner's new line of "RF" Electric Brakes, featuring the new, simplified replaceable-face design, offers precise, high speed stopping of loads up to 700 ft. lbs. (maximum static torque rating). With thicker, tougher friction surfaces, these new brakes stay in operation longer without adjustment. Wear take-up is completely automatic. They're foolproof against sudden, complete failure after extended usage. Wearing parts are easily and economically replaced to extend service life indefinitely. Clean, modern design, with only three main parts: armature, replaceable face, and magnet. Now in production—they're the newest, most advanced control for industrial machinery, farm equipment, and automotive accessory drives. Send coupon below for complete facts.

Beat competition with

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WARNER ELECTRIC BRAKE & CLUTCH CO., BELOIT, WISCONSIN

Warner Electric Brake & Clutch Co.
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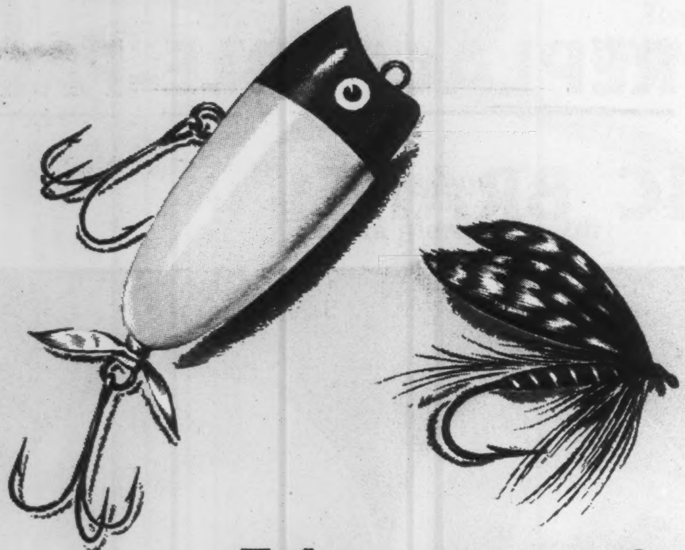
☐ Please send free catalog describing Replaceable-Face Electric Brakes.
☐ Have Warner Representative call.

Firm Name____________________
Individual________________Title________
Address____________________
City________________State________



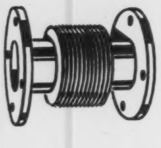
Take a moment . . .

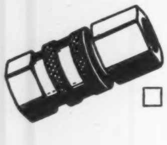
A second's glance will tell you there's a difference in purpose as well as shape between the lure and fly above. Companies differ in the same way and it won't take long to find that Titeflex is a "different" kind of company. Take originality—years of work on specially engineered jobs have made Titeflex people original in their thinking so you won't get routine answers to your $64 questions. More important, they know their business and you'll find you can talk over your troubles with them. And above all, Titeflex people are friendly, anxious to help. If you want to be treated individually, differently, you may like Titeflex a lot. Many others do. The coupon below will bring us together.

Titeflex

☐ Seamed and Seamless Metal Hose

☐ Ignition Harness and Shielding





☐ Precision Bellows

☐ Quick-Seal Couplings

Titeflex, Inc.
Industrial Products Division
508 Hendee Street
Springfield, Mass.

Please send me without cost information about the Titeflex products checked above.

Name____________________
Title____________________
Firm____________________
Address____________________
City__________Zone_____State_____

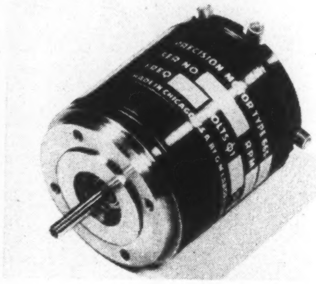
Left: Fresh water plug for Pickerel and Bass, Right: Fresh water fly for Brook, Brown and Rainbow Trout

sembly, operator positions the end fastener and power-drives a screw. Slight pressure then snaps secured fastener from the strip. Complete operation can be accomplished in less than 3 seconds. Made by **Tinnerman Products Inc.,** P. O. Box 6688, Cleveland 1, O.

For more data circle MD-111, Page 237

Servo Motors

High torque, low inertia, two-phase induction servo motors for use in electronic control circuits are available in 2, 4, and 8-pole models for 400 or 60-cycle current.

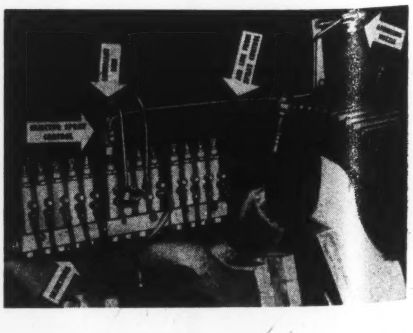


Standard frame sizes 15 and 18 have 1.437 and 1.750-in. diameters, respectively. Control phase can be wound for either series or parallel operation. Dielectric strength is maintained between windings and housings when at high altitudes. Made by **G-M Laboratories Inc.,** 4300 N. Knox Ave., Chicago 41, Ill.

For more data circle MD-112, Page 237

Automatic Mist Lubricator

Controlled mist lubrication for open gears is provided by spray control valve which operates automatically in conjunction with

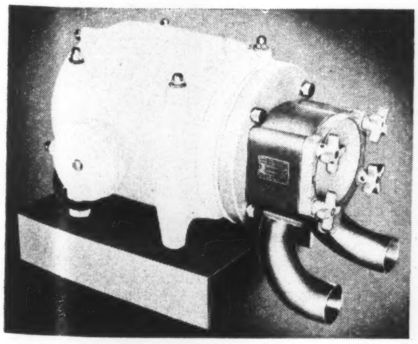


centralized lubrication systems. Valve can be assembled to any lubricant injector in the centralized system, mounted either adjacent to or remote from gears to be lubricated. As injector begins to discharge lubricant, spray control valve opens, allowing regulated air to pass spray nozzle, which atomizes lubricant into fine, uniform mist of air and lubricant. Output can be increased by diverting lubricant from two or more injectors through line to spray nozzle. Made by **Lincoln Engineering Co.,** Industrial Div., 5736 Natural Bridge Ave., St. Louis 20, Mo.

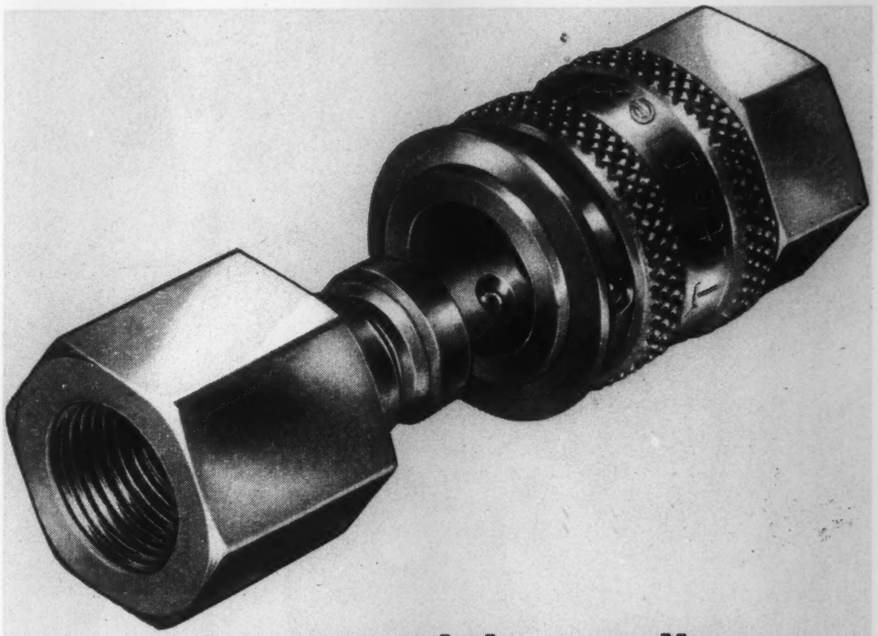
For more data circle MD 113, Page 237

Sanitary Pump

Highly resistant to corrosion and contamination, close-coupled Sani-Flex pump meets requirements for pumping food products, pharmaceuticals and chemically pure fluids. Gentle pumping action prevents churning or foaming of the fluid. Pump handles viscous materials or abrasive slurries efficiently, since fluid does not come into contact with actuating mechanisms or rotating parts, but only with stainless steel housing and the outside surface of a tasteless and odorless Neoprene or other synthetic or gum rubber liner. The only wearing part is the easily replaceable flex-i-liner. Design eliminates the need for stuffing boxes and packing glands or shaft seals, thereby avoiding the possibility of external leakage, as well as insuring against



(*Continued on Page* 296)



end your quick coupling problems the QUICK-SEAL way

If you haven't seen the new Titeflex QUICK-SEAL Straight-through and Check-valve Couplings—you have a pleasant surprise coming. These new Couplings . . .

1. Are leakproof. The higher the pressure, the tighter the seal.
2. Couple and uncouple in ONE SECOND—without tools.
3. Prevent hose kinking—through their 360° swivel action.
4. Are slim, easy to handle, not awkward and bulky.
5. Have no projections to snag or bend.
6. Have heat-treated steel bearing surfaces and stainless steel ball bearings and springs for long life.
7. Are made in a variety of alloys and in many sizes up to 12" diameter. Are interchangeable in the same size.

Titeflex QUICK-SEAL Couplings are made in the following types—Straight-through, Single- and Double-Check-valves. The Straight-through type has a smooth bore for free flow without obstructions. *Write today for Titeflex QUICK-SEAL Coupling Catalog.*

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Titeflex, Inc.
Industrial Products Division
508 Hendee Street
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Titeflex
QUICK-SEAL COUPLINGS

I'm interested in the possibilities for your new Quick-Seal Hose Coupling. Send me complete catalog—no obligation of course.

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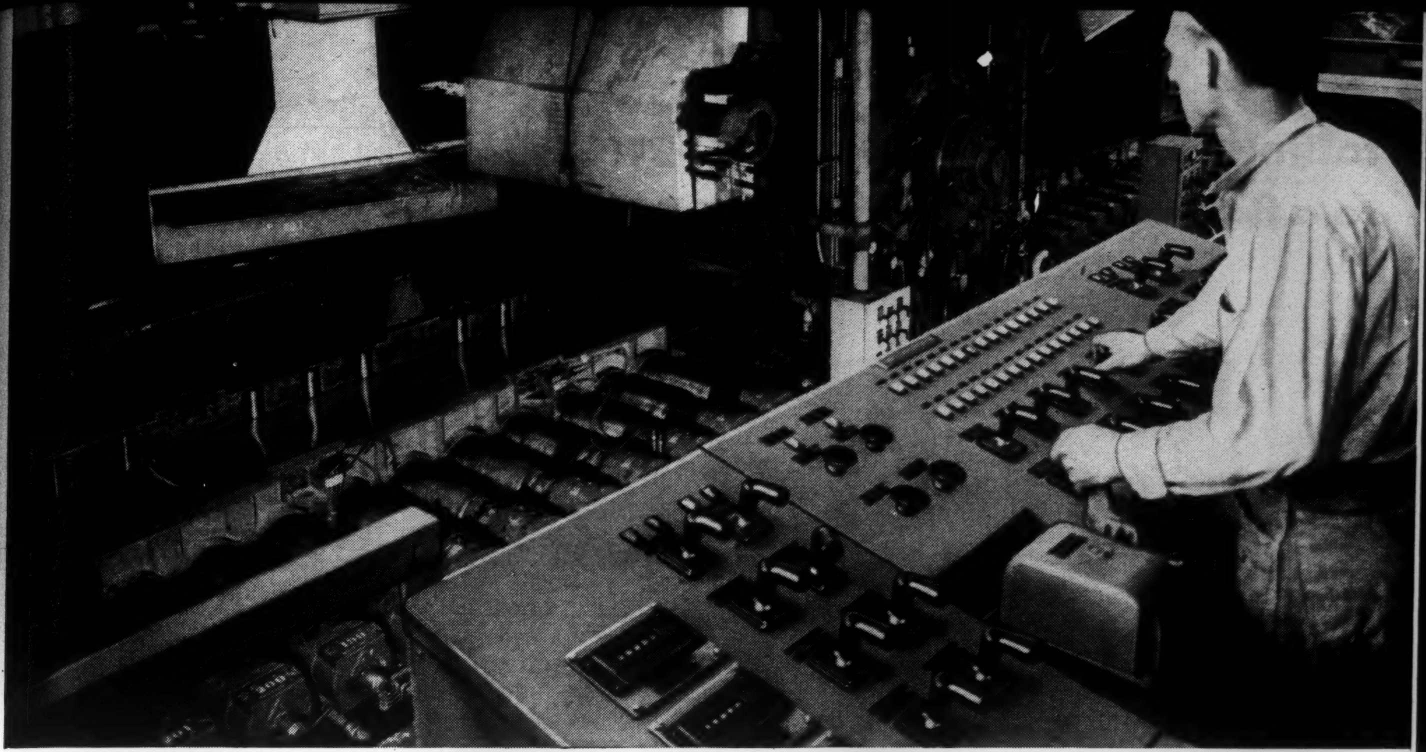
The HIGHER the Pressure the TIGHTER the Seal

FIVE TONS OF "LIGHT WEIGHT"! Known everywhere as the "world's lightest structural metal," it's something new indeed to see magnesium rolling ingot in five-ton lengths being lowered away to huge saws in rooms beneath the earth—where shorter ingots can be prepared for rolling in Dow's new coil mill.



Operator's touch controls slab movement through 84″ rolls.

look at Magnesium!

UP TO 25% PRICE REDUCTION ON PLATE & SHEET

Now Available! Tremendous new Dow facilities, now in operation, are geared to supply large quantities of magnesium plate, sheet and extrusions—in many new sizes, shapes and forms. Years of experience with magnesium were combined with newest *volume production techniques* to create the world's first 84-inch coil mill for rolling magnesium. If you are a designer, engineer or manufacturer—anxious to cut costs and improve products—it's time to take a *new look* at strong, lightweight magnesium! Call the nearest Dow office or write today for information—THE DOW CHEMICAL COMPANY, Magnesium Sales Department, Midland, Michigan.

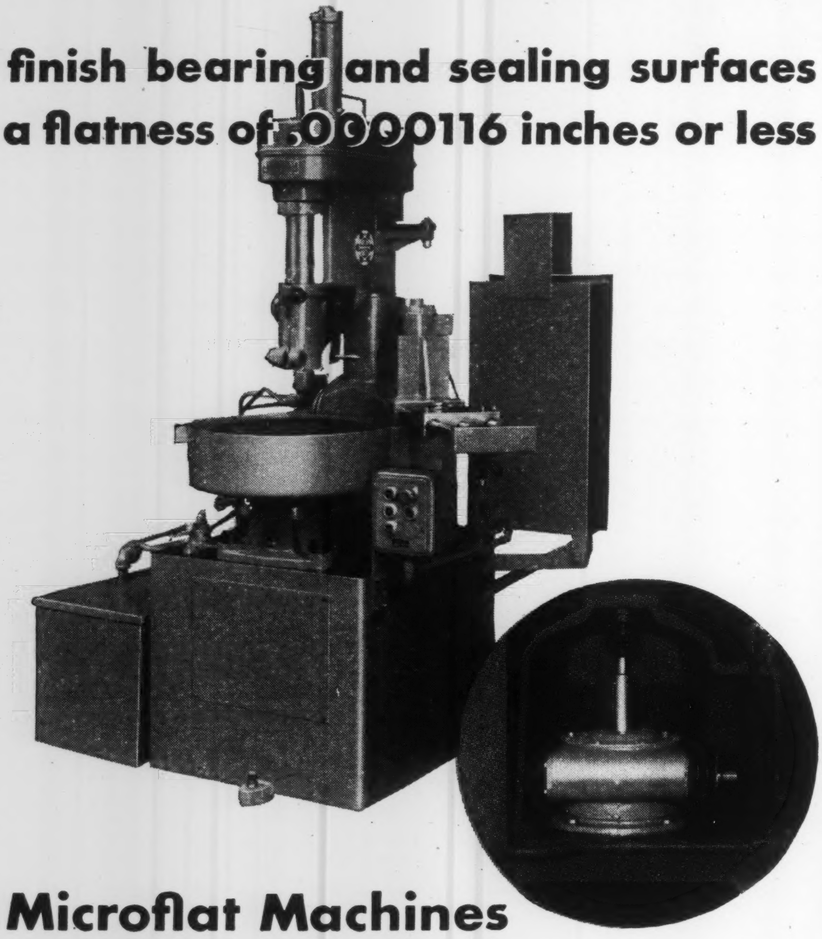
MAGNESIUM PLATE—Light, strong magnesium tread plate—lengths to 16 feet, widths to 6 feet, thickness to 2 inches.

MAGNESIUM SHEET — New production facilities and rigid inspection insure top quality magnesium products.

MAGNESIUM COIL—Note size of coil, illustrates new availability in greater widths and lengths.

you can depend on DOW MAGNESIUM

DOW



to finish bearing and sealing surfaces to a flatness of .0000116 inches or less

...Microflat Machines use WINSMITH Speed Reducers

Whether it's soft non-ferrous metal, hardened steel or ceramic . . . any flat surface that can be machined, can be finished to any desired degree of flatness and surface finish on this Microflat Machine.

Mounted in a holding fixture, the work piece rotates and oscillates across a rotating finishing plate. Assuring correct speed for accurate abrading is a motor-driven Winsmith Worm Gear Speed Reducer, Model 6 BV, with an input of 3 hp at 1800 rpm and a reduction ratio of 16⅔ to 1.

"We have chosen the Winsmith Reducer because of its dependability . . . both in service and in meeting fast delivery schedules," reports Micromatic Hone Corporation, Detroit, Michigan.

Dependability of product and Company is a principal reason for the continual preference of rugged, compact Winsmith Reducers within the 1/100 to 85 hp range, in ratios from 1.1:1 to 50,000:1. Make sure your organization has the facts on this complete line of differential, worm gear, helical gear and worm-helical units.

For details, request Catalog 148 . . . and for information on Winsmith's new "C" Line Worm Gear Speed Reducers, request Bulletin 654.

WINSMITH, INC.
16 ELTON ST.
SPRINGVILLE (Erie County), N. Y.

WINSMITH
SPEED REDUCERS

MEMBER OF AGMA

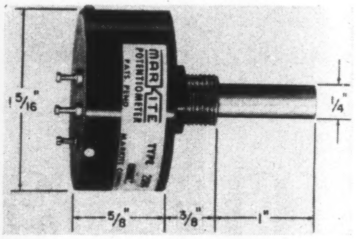
(Continued from Page 293)

contamination of the product from lubricants or other external sources. Made by **Vanton Pump & Equipment Corp.,** Empire State Bldg., New York 1, N. Y.

For more data circle MD-114, Page 237

Rotational Potentiometer

Type 2094 potentiometer is designed for applications requiring long life, substantially infinite resolution and low noise under extreme vibration and acceleration.

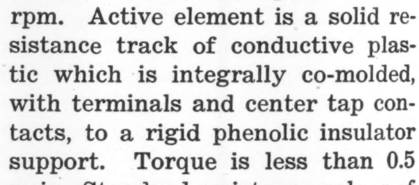


It will perform 5 million revolutions at maximum speed of 600 rpm. Active element is a solid resistance track of conductive plastic which is integrally co-molded, with terminals and center tap contacts, to a rigid phenolic insulator support. Torque is less than 0.5 oz-in. Standard resistance values of 2000 to 100,000 ohms with linearity of 0.5 or 1 per cent are available. Power rating is 2 w at 820 C. Made by **Markite Corp.,** 155 Waverly Place, New York 14, N. Y.

For more data circle MD-115, Page 237

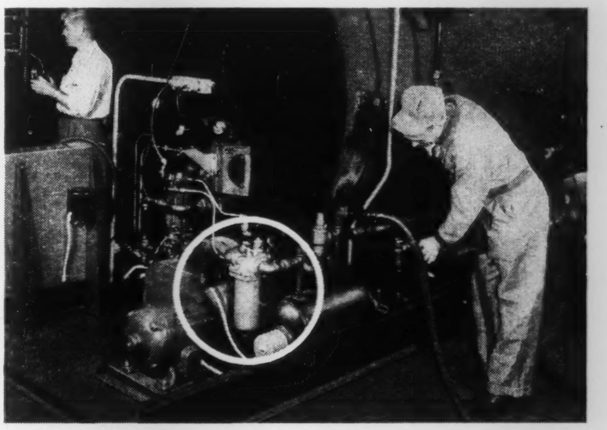
Magnetic Counter

Measuring ⅞-in. high and 2 in. long, magnetic counter is adaptable to various industrial and experimental functions. It adds and subtracts and is offered with three

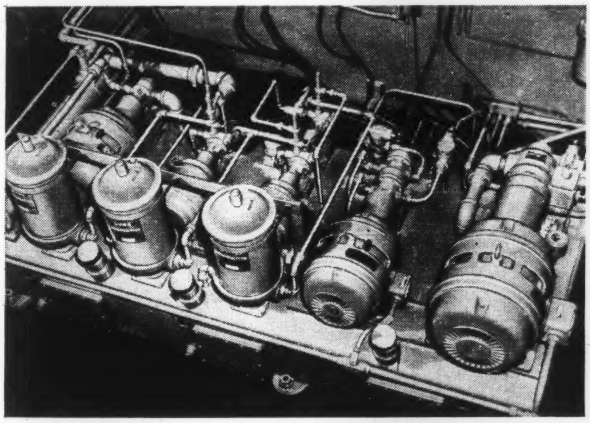


If you can pump it — Cuno can filter it

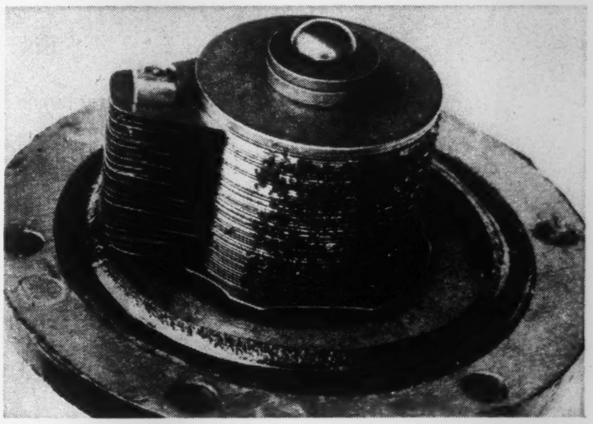
POWERFUL LeTOURNEAU-WESTINGHOUSE Tournapulls, equipped with Cuno MICRO-KLEAN 2-element lube oil filters, work efficiently in areas inaccessible to other earthmovers. When they've got a tough filtration problem, leading manufacturers like LeTourneau-Westinghouse know they can depend on Cuno for the right answer.



FUEL OIL. Leading boiler manufacturer uses continuously cleanable, all-metal Cuno AUTO-KLEANS to filter #6 and #7 fuel oil. He says, "... filter results are very satisfactory. Maintenance of filter is at the minimum." AUTO-KLEANS come in steel, brass or stainless; capacities range all the way from 1 GPM to 3,760 GPM.



HYDRAULIC FLUID. 50-micron Cuno MICRO-KLEAN filters protect precision parts in hydraulic and lube systems of way bed and worm drive box on this horizontal broach. MICRO-KLEAN provides full-flow filtration and protects cylinder rams, liners, valves and other parts.



LUBE OIL. Specially designed AUTO-KLEAN filter after green run in the lubrication system of automotive-type gasoline engine in military service. Note the core sand, sealing paint, lint and metal chips accumulated after only a few hours' operation — graphic proof of the need for full-flow filtration here.

10.4.16

CUNO

ENGINEERED FILTRATION

Removes More Sizes of Solids From More Kinds of Fluids

AUTO-KLEAN (disc-type) • MICRO-KLEAN (fibre cartridge) • FLO-KLEAN (wire-wound)

CUNO ENGINEERING CORPORATION

DEPT. 20 SOUTH VINE STREET MERIDEN, CONN.

I'm interested in effective filtration of fuel oil ☐

lube oil ☐ water ☐ coolant ☐ hydraulic fluid ☐

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(other fluid)

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Bulletin ☐

NAME____________________

COMPANY____________________

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CITY__________ZONE____STATE__________

precision potentiometers by DeJUR

Simplify your design problems

RUGGEDIZED METERS

STANDARD AND POWER POTENTIOMETERS

DUAL UNIT CONSISTING OF 2 SERIES HP-300 HIGH RESOLUTION, LOW TORQUE LINEAR POTENTIOMETERS

Choice of turret terminals (illustrated) or tinned solder lugs

3", high resolution linear potentiometers

Extremely fine settings and readings, plus better linearity and low physical height are achieved in the Series HP-300 Potentiometer through a combination of long winding length and a small diameter cylindrical Kohlrausch winding. Torque is minimized through use of fine resistance wires and pitches. The unit features 360° mechanical rotation and 356° electrical rotation ± ½°.

Series HP-300 potentiometers are available as single units or ganged multiples with up to sixteen taps per section. Taps and end connections are available in either silver plated turret terminals or semi-flush tinned solder lugs. Housing is one piece molded low loss Bakelite—end plates of precision turned blue Alumilite finished aluminum.

For complete illustrated engineering literature, plus other designs for special applications, write Dept. MD, DeJUR-Amsco Corporaton, 45-01 Northern Blvd., Long Island City 1, N. Y.

SEALED METERS SQUARE AND ROUND

FULLY ENCLOSED POTENTIOMETERS

HIGH RESOLUTION POTENTIOMETERS

Electronic Sales Division DeJUR

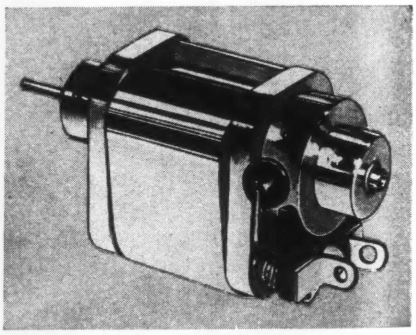
45-01 NORTHERN BLVD., LONG ISLAND CITY 1, N. Y.

or four digits. Manually reset counter wheels record to a maximum recommended speed of 1200 counts per minute. Unit is actuated electromagnetically and can be connected in vacuum tube plate circuits or operated by any contacting device. Units are available with or without cases, and a snap door on front of case allows resetting. Windings are to any voltage from 6 to 110 v dc. Made by **Abrams Instrument Corp.**, 606 E. Shiawassee St., Lansing 1, Mich.

For more data circle MD-116, Page 237

Precision Motor

Although this motor has dimensions of ¾ x ⅞ x 1⅜ in., it develops 1/500-hp. Speed range is 5000 to 20,000 rpm. Motor operates on 1½ to 28 v dc. Torque is 0.20-oz-in. Made by **Small Motors Inc.**, 2076 Elston Ave., Chicago 14, Ill.



For more data circle MD-117, Page 237

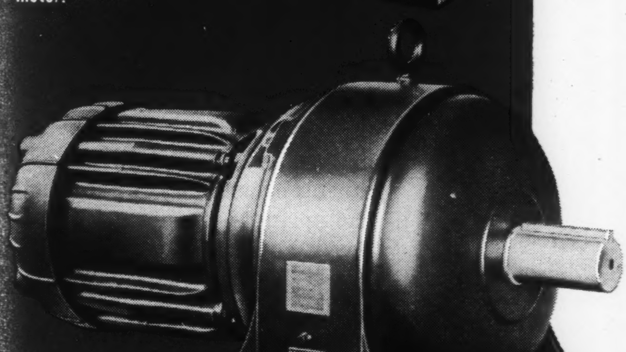
Air Control Valves

Pipe sizes ranging from ¼ to 1 in. are available in series of in-line valves consisting of 47 models. Variations include two or three-way action, solenoid or remote pilot actuation and line or foot-mounting. Complying with all JIC design standards, valves are claimed to be the first of their type to provide a fully enclosed solenoid. Pilot-operated, they function efficiently at pressures as low as 5 psi. Exhaust can be throttled to control speed. Sole-

The speed you want...where you want it!

Single reduction gearmotor with Elliott C-W brake. A complete integral power unit. Low speed shaft can be located with reference to motor center-line in any of four positions—above, (as shown) at right, left, or below.

Double-reduction gear on an Elliott C-W Form BA squirrel cage motor.



Triple-reduction unit mounted on an Elliott C-W totally-enclosed fan-cooled "Sealedpower" explosion-proof motor.

W3-10

ELLIOTT
CROCKER-WHEELER
Gearmotors

Here is a complete line of motors with built-in reduction gear units which covers practically every need.

Available in any motor type, any enclosure, any mounting, in frame sizes from 1 to 150 hp.

Single reduction, 780 to 280 rpm... double reduction, 230 to 45 rpm... triple reduction, 37 to 7.5 rpm.

Construction features include precision processed, file-hard gears, large oil reservoir for abundant splash lubrication, heavy, rigid cast iron pyramidal base, and a bearing housing and oil seal *separating* the inner high speed motor bearing from the gear lubrication, which after much service may contain minute metallic particles tending to shorten bearing life.

GET THE GEARMOTOR DATA BOOK
— ask your local Elliott District Office or write direct to Elliott Company, Crocker-Wheeler Division, Ampere, N. J.

ELLIOTT Company

STEAM TURBINES • MOTORS • GENERATORS • DEAERATING HEATERS • EJECTORS • CONDENSERS
CENTRIFUGAL COMPRESSORS • TURBOCHARGERS • TUBE CLEANERS • STRAINERS

Leach CORPORATION
PRESENTS
"The Ultimate in Controls"

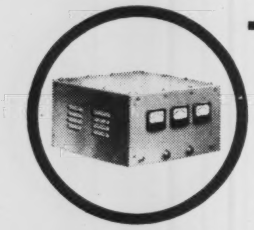
Through modern research, engineering, development, design and production techniques, *Leach* CORPORATION presents electrical control units you will want to investigate . . . *immediately!* Take advantage of the savings they provide and, the *unsurpassed* performance characteristics they incorporate.

INET RX60 Voltage Regulator

Using a completely static system, the RX60 has been designed to provide precise Voltage Regulation for all 60 cycle equipment.

Available in range from 1 KVA to upwards of 5000 KVA, the RX60 can be regulated to ±½%. It is adaptable to any machine with an exciter or will provide its own excitation if necessary.

Having no tubes, contacts or other electronic devices, the RX60 will last indefinitely with a minimum of maintenance.



INET RX400 Voltage Regulator

The RX400 also incorporates all static components and is made to give the same features of long life and low maintenance for 400 cycle applications.

Adaptable to all 400 cycle alternators, the RX400 will regulate voltage to ±½%, no load to full load.

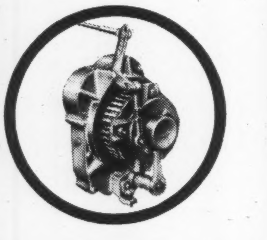
This unit is recommended for use where precise regulation is important, such as Ground Power Supplies, Testing Aircraft Instruments, and in Guided Missile applications.

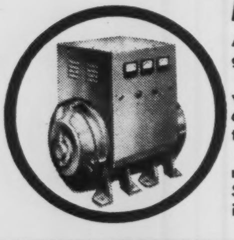
INET DUPY Electro-Mechanical Governor

The DUPY is a load-sensing, electro-mechanical governor used for controlling the speed of a gas or diesel engine. In controlling this speed the DUPY holds D. C. Voltage stable and A. C. Frequency constant under *all load conditions.*

Extremely simple in design, the DUPY can be fitted to any make or model gas or diesel engine by the use of a simple adapter mounting.

Through the use of the DUPY governor, time between engine overhauls can be increased by several hundred percent.





PALMER Series 60 and 400 Alternators

A completely new line of 60 and 400 cycle alternators designed to give exacting frequency output.

Meeting all military and civilian requirements of perfect sine-wave, low harmonic content and precise output, PALMER "Series 60 and 400" alternators are ideal for aircraft, guided missile industries and industrial commercial application.

The "Series 60" may be coupled to any prime mover—gas, diesel, natural gas, etc. The "Series 400" is available as a 2-bearing M-G Set or may be purchased for use with any of the above type engines in 2 or 4 bearing units.

For the "Ultimate in Control" use a *Leach* CORPORATION "Precise Power Package". . . PALMER 60 or 400 cycle alternators, INET RX Voltage Regulators—DUPY Governors. These units are designed to provide exacting regulation and performance.

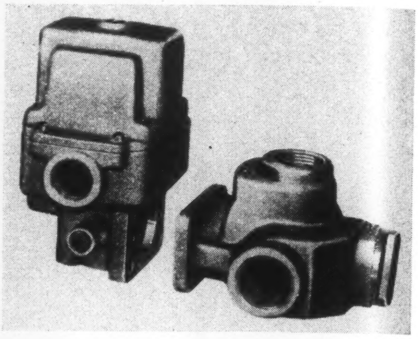
Write for Bulletins describing these products in detail.

Leach CORPORATION has outfitted a demonstration truck with all of the above operating equipment. Private and public showings are scheduled throughout the country. Write for date the truck will be in your vicinity.

Research
Development
Design
Production

Leach CORPORATION
5915 Avalon Blvd., Los Angeles 3, California
District Offices and Representatives in
Principal Cities of U. S. and Canada

SPECIALISTS IN ELECTRIC & ELECTRO-MECHANICAL CONTROLS

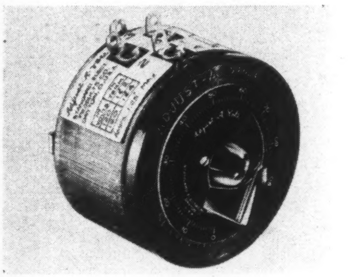


noid pilot head, illustrated, and remote pilot heads are interchangeable on the main valve assembly. Made by **Numatics,** Milford, Mich.

For more data circle MD-118, Page 237

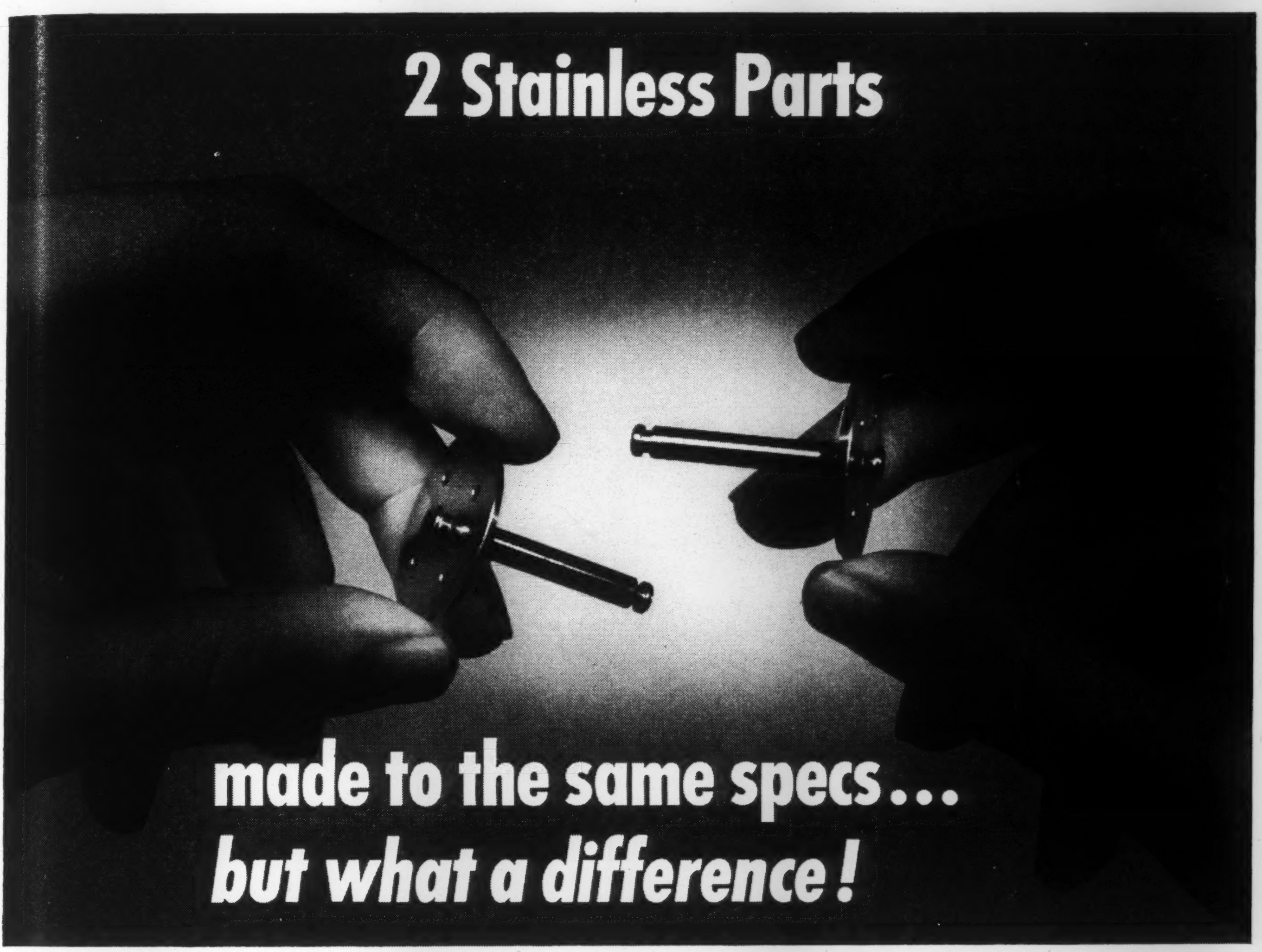
Variable Transformer

Compact Adjust-A-Volt model 100BU, for 50, 100 and 150-w loads, is a toroidally wound, hydrogen-annealed auto-transformer that will deliver smooth and continuous output voltages from zero to above line voltage. Voltage is adjustable with good regulation and no waveform distortion. Transformer has an extra-long brush spring which allows free action and maintains constant brush pressure during brush life. A safety stop on the spring prevents contact of the brush holder and winding when the brush has completely worn down. LoRes alloy brush track plating eliminates deterioration of the commutation surface and assures long life. Transformer is rated single phase, 60 cycle, 120 v input; 0 to 120 v output, 1.25 output amp, 150/165 va. Made by **Standard Electrical Products Co.,** 2240 E. Third St., Dayton, O.



For more data circle MD-119, Page 237

2 Stainless Parts



made to the same specs...
but what a difference!

Machining costs are 25% lower

This valve is used for a fuel return regulator check. Although the manufacturer was one of the first to use Carpenter Stainless No. 8 (Type 303) when it was first introduced, there have been occasions and conditions which required the use of ordinary makes of Type 303 Stainless Steels. The customer reports: Carpenter No. 8 *consistently* enables them to show a 25% saving in machining costs because of its constant uniformity and easier machinability.

Reject rate is reduced

An important requirement of this valve is that it be "leak-proof" in operation under pressure. To assure a tight seal, some surfaces are machined to a 5 or 10 micro-inch finish with tolerances as close as .0005″. Because of the machinability and finishes obtained with Carpenter No. 8, rejects always take a sharp drop when compared with competitive Type 303 Stainless Steels.

Machine operators are happier

Here's an interesting sidelight: Machine operators can always spot an ordinary Type 303 without being told, because of the way it cuts in the machines. With Carpenter No. 8 they tell us they *know* the job will run smoother and faster with improved results. The same thing can apply in your *own* plant. So if you're looking for a way to improve performance and reduce costs on your stainless parts, CHANGE to Carpenter No. 8. See what the difference can mean to you. THE CARPENTER STEEL CO., 120 W. Bern St., Reading, Pa.

take the problems out of production

... change to Carpenter STEEL

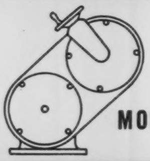
Free-Machining Stainless

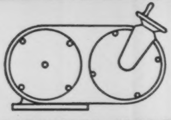
IMMEDIATE DELIVERY from local warehouse stocks!

Export Department: The Carpenter Steel Co., Port Washington, N.Y.— "CARSTEELCO"

REEVES
Fractional HP Motodrive

NEW!
REEVES
10:1
SPEED RANGE





NEWEST DESIGN FOR VARIABLE SPEED
112 ASSEMBLIES
to choose from— engineered to your exact requirements!

CHECK ALL THESE NEW, REEVES FEATURES

1 New redesigned, more compact drive gives you speeds from 3 to 4660 RPM . . . speed ranges from 10 to 1!
2 New "all-position," 14-turn handwheel gives operator sensitive, minutely-accurate speed control from a position most convenient for the installation!
3 New "all-position" output shaft permits driving in any direction—horizontal or vertical down!
4 New spiral groove lubrication with exclusive overflow outlet provides complete lubrication of all sliding surfaces for trouble-free operation at all times!

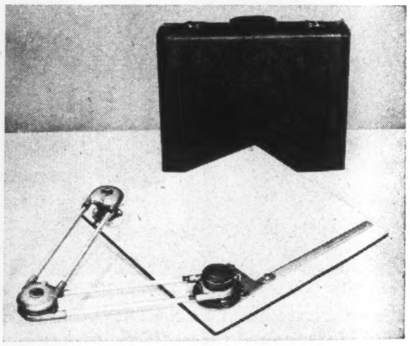
REEVES PULLEY COMPANY • COLUMBUS, INDIANA

Send Today for Complete Information!
Specify Bulletin H7b-M543.

ENGINEERING DEPARTMENT EQUIPMENT

Portable Drafting System

Desk-Topper drafting and layout system consists of a drafting machine with a drawing capacity of 22 x 34 in.; 9-in. and 15-in. engine-divided aluminum alloy scales; a folding board equipped with folding legs and rubber feet that, when opened, accommodates drawings up to 17 x 22 in.; a box for instruments; a tracing paper dispenser and a carrying carton or travel case. Equipment also includes a 4-in. diameter, 360-deg protractor with automatic 15-deg indexing; full base line selector; double 10′ vernier and clamp; screw clamp; enclosed band and pulley arms and built-in brake for 10-deg board slope. Vertically adjustable mounting permits direct layout work on sketch pads, plywood, sheet metal or any other material up to ¾-in. thick. Five scale styles make the Desk-Topper adaptable to many types of work. Made by **Universal Drafting Machine Corp.,** 7960 Lorain Ave., Cleveland 2, O.



For more data circle MD-120, Page 237

Copying Machine

Verifax printer will copy documents up to 8½ x 14 in. by a simple transfer process. Machine can be used on any desk or table under normal light conditions. Rate

One Priceless Element In Every

POPE PRECISION SPINDLE

THE *Confidence* OF ITS USER

You can have complete *confidence* in the anti-friction bearings POPE puts into your spindles.

They are made to new super-precision tolerances.

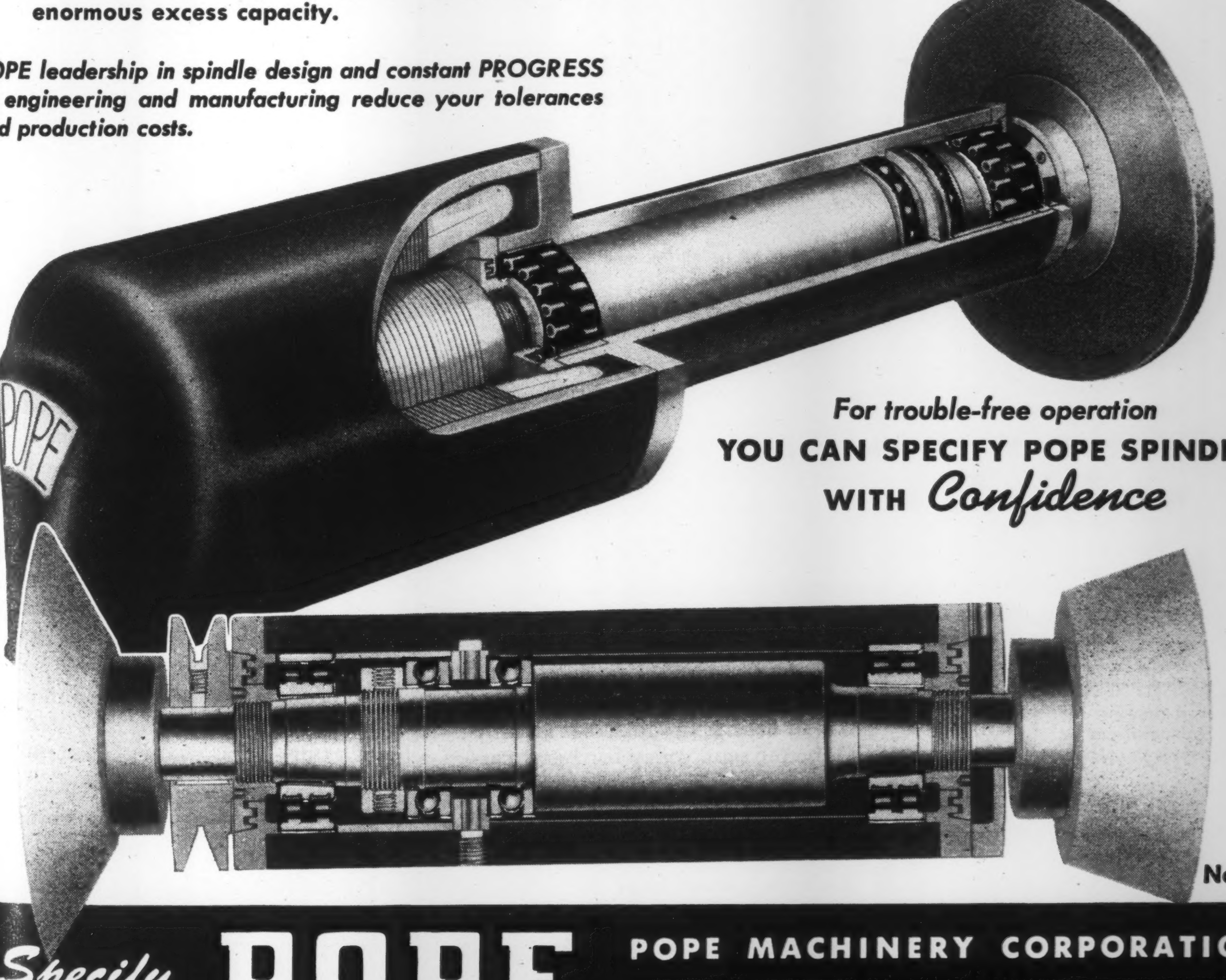
You can depend upon Pope Spindles for the continuous production of accurate parts, fast removal of the surplus metal and fine *low* micro-inch surface finishes.

POPE Spindles have radial and axial rigidity capable of properly supporting modern cutting tools on high production work.

The shafts are large for extra rigidity and have enormous excess capacity.

With the POPE SYSTEM of Grease Lubrication used successfully for thirty-four years, there is no internal radial clearance for oil film in the bearings — none is required. Instead, the bearings are permanently internally preloaded for accurate centering and positioning of the shaft.

POPE leadership in spindle design and constant PROGRESS in engineering and manufacturing reduce your tolerances and production costs.



For trouble-free operation

YOU CAN SPECIFY POPE SPINDLES WITH *Confidence*

No. 103

Specify POPE

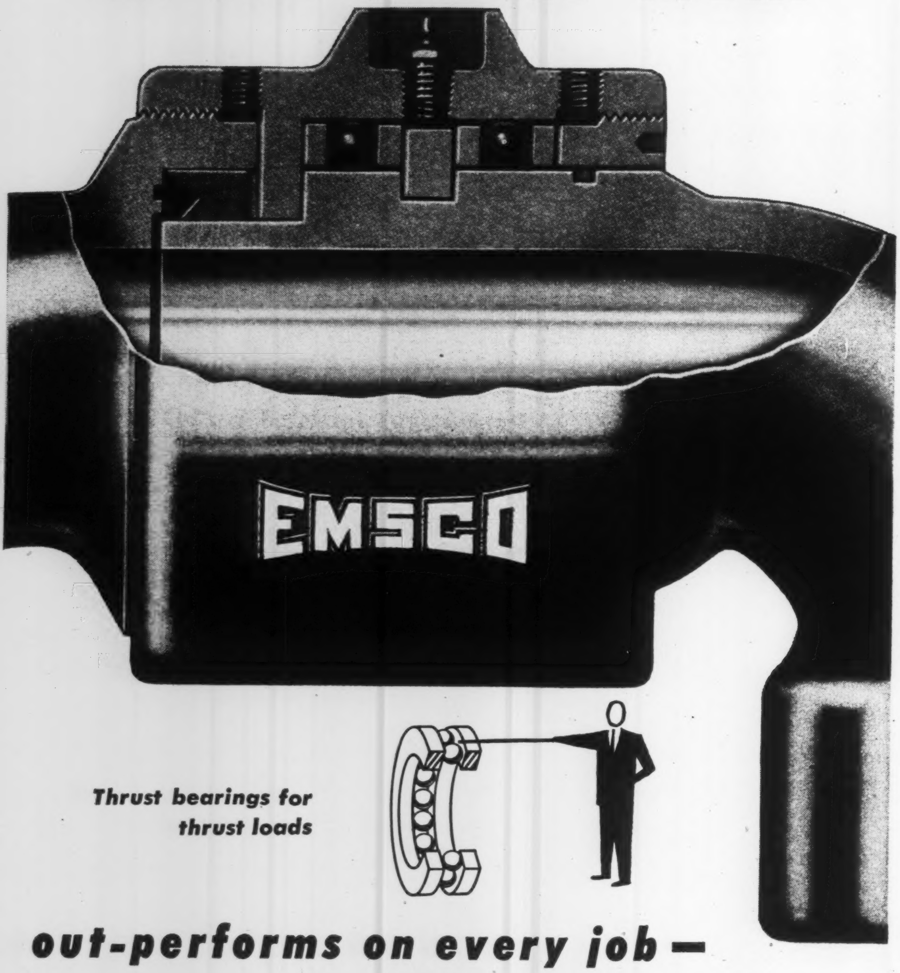
PRECISION SPINDLES

POPE MACHINERY CORPORATION

Established 1920

261 RIVER STREET • HAVERHILL, MASSACHUSETTS

FINEST SWIVEL FITTING ON THE MARKET TODAY



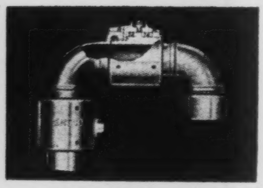
Thrust bearings for thrust loads

out-performs on every job — yet costs no more

Throughout the world, you'll find EMSCO Ball Bearing Swivel Fittings on vital installations where safety, free-turning and low resistance to flow are essential.

Compare EMSCO ball race design — thrust bearings for thrust loads. Compare the method of sealing against leakage — an isolated packing chamber in which is retained the type of packing most suited to the job. Fitting breaks like a union for easy inspection or replacement of packing.

You profit directly from these features — the result of years of engineering know-how built into every EMSCO fitting. If you're not already using EMSCO, better send today for latest catalog and prices.



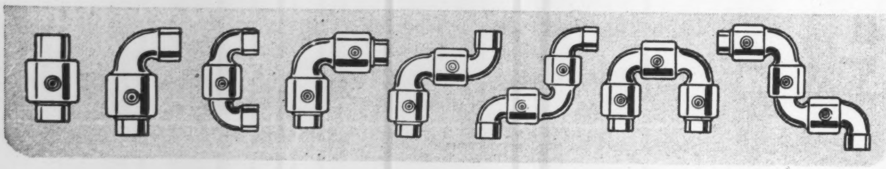
STYLE 5 U.S. TYPE

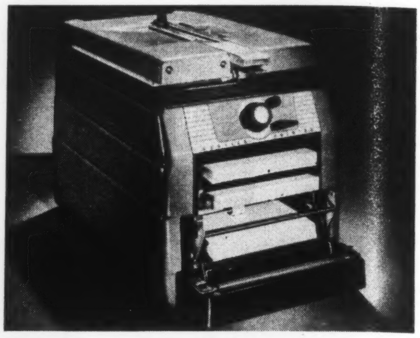
Grooved packing for high temperatures or corrosive services.

Lip type packing for high pressures.

EMSCO MANUFACTURING COMPANY

Box 2098, Terminal Annex
Houston, Texas LOS ANGELES 54, CALIF. Garland, Texas



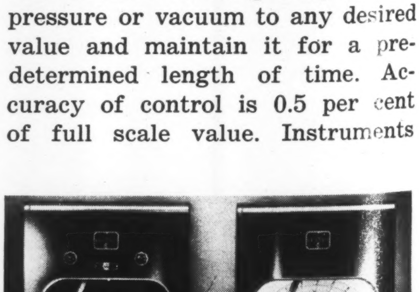


of production is about three copies per minute. Paper compartments, removable for easy loading, hold 100 sheets each. Supplementary reservoir keeps activator solution fresh and at proper level. Unit also has an electrical timer for exposure and activating, provision for handling over-size originals and an independent print paper feed. Underwriters' approved, it operates from standard 110-v power source. Made by **Eastman Kodak Co.**, Rochester 4, N. Y.

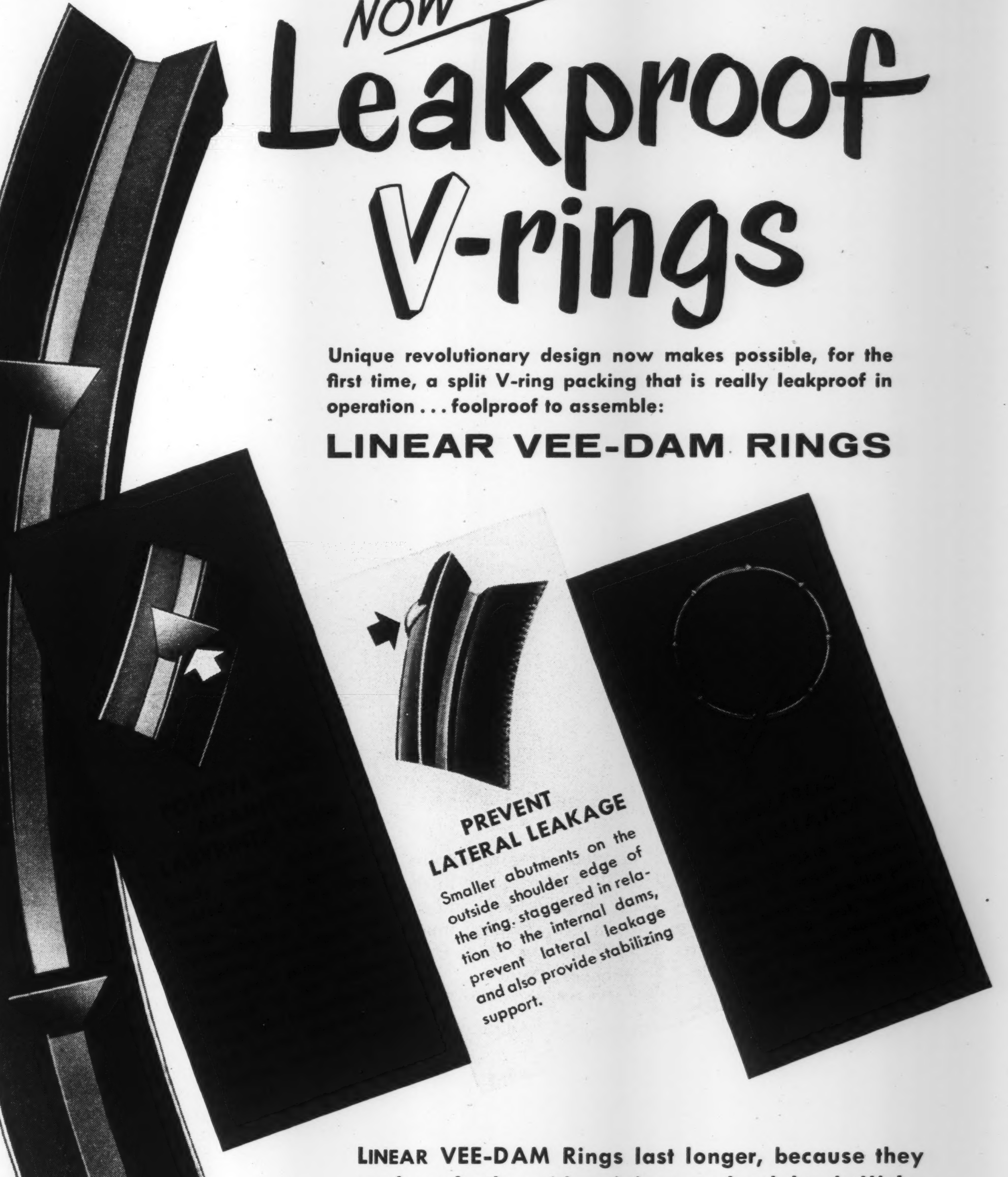
For more data circle MD-121, Page 237

Control Instruments

Line of control instruments for use with any environmental test cabinet can be used to initiate and maintain an entire program of varying climatic conditions and to simulate any temperature, humidity or altitude conditions. A plastic or aluminum cam serves as a template for the program. Available in one or two-case models depending on application, the controllers will carry through the program repeatedly and reproduceably. They can also be used to bring temperature, pressure or vacuum to any desired value and maintain it for a predetermined length of time. Accuracy of control is 0.5 per cent of full scale value. Instruments



NOW Leakproof V-rings



Unique revolutionary design now makes possible, for the first time, a split V-ring packing that is really leakproof in operation . . . foolproof to assemble:

LINEAR VEE-DAM RINGS

PREVENT LATERAL LEAKAGE

Smaller abutments on the outside shoulder edge of the ring, staggered in relation to the internal dams, prevent lateral leakage and also provide stabilizing support.

LINEAR VEE-DAM Rings last longer, because they seal perfectly with minimum gland load. We're molding VEE-DAM Rings, in a choice of fabric-reinforced elastomers, individually engineered to your needs. Write or call for full information now!

LINEAR

First line of defense against...
DAMAGE
DAMPNESS
DIRT
DUST

S.S.WHITE

ELASTOPLASTIC

PLUGS AND CAPS

When you make an expensive part, it's good business to protect it against needless damage during shipment and storage. The way to do this – at minimum cost – is with S.S.White Elastoplastic Plugs and Caps.

These inexpensive flexible plastic closures are designed to cover or seal important openings or studs. They keep dirt and moisture out of interior parts –protect ends of tubing and studs – and seal in hydraulic fluids.

Besides being low in cost, S.S.White Elastoplastic Plugs and Caps are easily applied and removed – they're unaffected by oil, grease and gasoline and are available in a wide range of sizes for every need.

WRITE FOR BULLETIN P-5312

It has full details on S.S.White Elastoplastic Plugs and Caps. Sample plugs and caps can also be furnished on request.

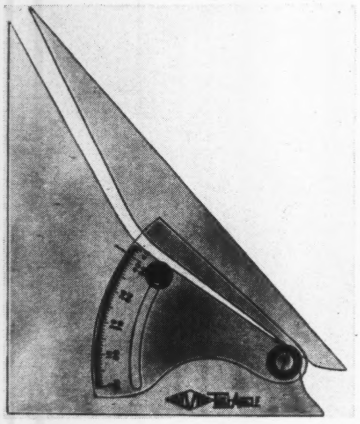
THE S.S.White PLASTICS DIVISION
DENTAL MFG. CO.
Dept. MP, 10 EAST 40th ST., NEW YORK 16, N.Y.
[illegible] District Offices • [illegible]

are available with electric on-off or proportional-input control, or with pneumatic control in proportional, reset or derivative models. Made by **Bristol Co.,** Waterbury 20, Conn.

For more data circle MD-122, Page 237

Adjustable Triangle

Fluorescent adjustable triangle is made of orange-tinted acrylic fluorescent plastic and produces a self-illuminating orange light from all edges. Contrasting die-sunk graduations are in black on a transparent protractor facing, with beveled edges to eliminate the possibility of parallax lines. Outer row of graduations indicates angles from 0 to 45 deg; inner row, from 45 to 90 deg. Made by **Alvin & Co.,** Windsor, Conn.



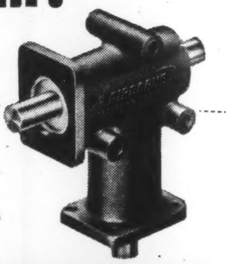
For more data circle MD-123, Page 237

Whiteprinting Machine

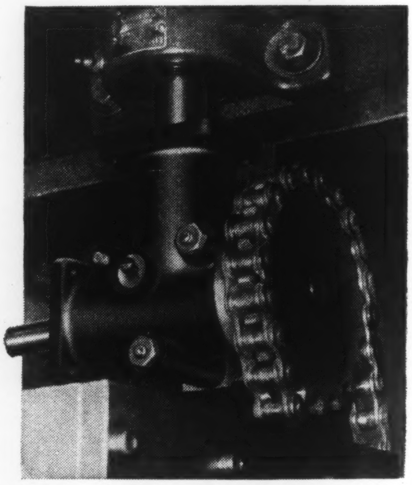
Model 800 reproduces translucent engineering drawings up to 42 in. wide continuously and automatically. An electronic adjustable-speed drive in printer section permits instant changes to any speed from 8 in. to 30 ft per minute. Dry development section has a thermostat control to maintain the temperature required for uniform development. Vapor circulation is automatically co-ordinated with different speeds. Full development is assured by jet type atomizer which forces ammonia under pressure into a vaporizing

ANGLgear
TRADE MARK

solves another problem!



The ORIGINAL right-angle bevel gear unit



Photograph courtesy Fort Wayne Metals, Inc.

PROBLEM: A right-angle power take-off needed for wire coiling machine turning on vertical axis.

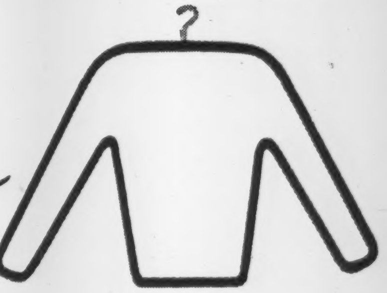
SOLUTION: ANGLgear.

COMMENTS: after 10,000 hours of *continuous* use at up to four times rated capacity, unit is in perfect shape—keeping up with production schedule!

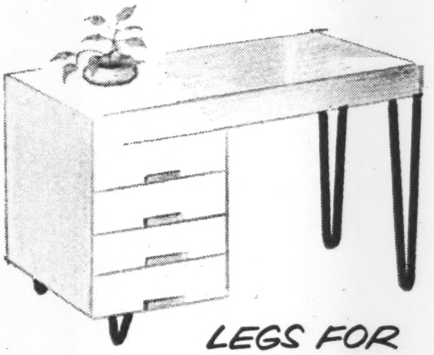
ANGLgears are rated up to 1 hp at 1800 rpm. Both models are made with 1-1 gear ratio, and with 2 or 3-way shaft extensions. Contact your local distributor or write to us for information.

AIRBORNE
Accessories Corporation
HILLSIDE 5, NEW JERSEY

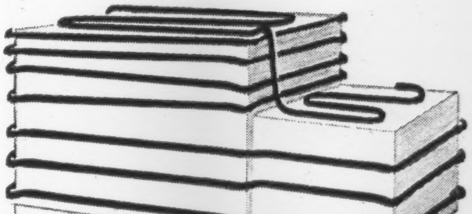
FROM *the Bundy Sketchbook* TO *jog a designer's imagination*



SWEATER DRYING FORM

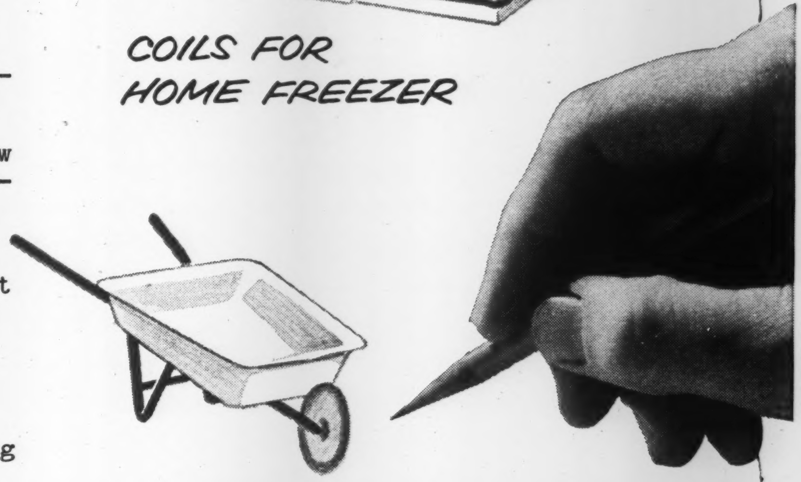


LEGS FOR MODERN DESK



COILS FOR HOME FREEZER

REMARKS Are complicated tubing snarls eating into profits? Why not let skilled Bundy engineers show you how to simplify fabrication operations; save time, money, materials. Why not check, too, the advantages of using strong, lightweight Bundyweld, the only tubing double-walled from a single metal strip.



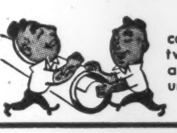
FRAME FOR TOY WHEELBARROW

WRITE today for catalog or for help in developing your tubing application.

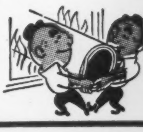
BUNDY TUBING COMPANY
DETROIT 14, MICHIGAN

WHY BUNDYWELD IS BETTER TUBING

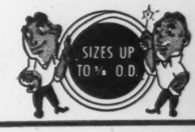
Bundyweld starts as a single strip of copper-coated steel. Then it's . .



continuously rolled twice around laterally into a tube of uniform thickness,



and passed through a furnace. Copper coating fuses with steel. Result . . .



SIZES UP TO ¾ O.D.

Bundyweld, double-walled and brazed through 360° of wall contact.

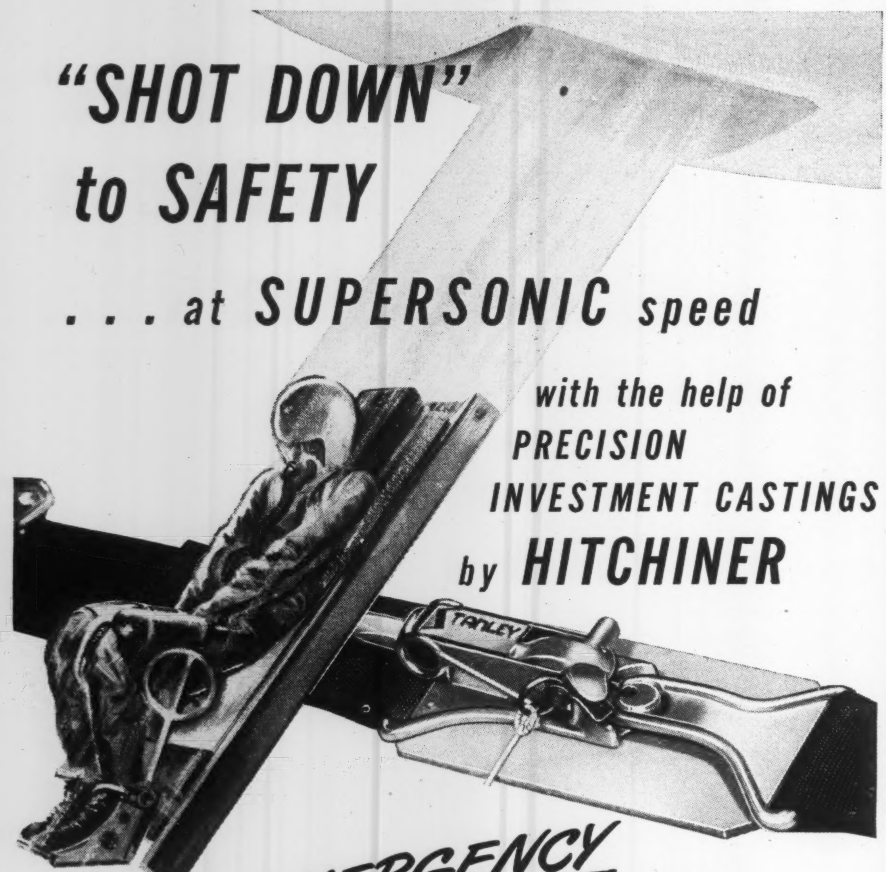
BUNDYWELD TUBING®

DOUBLE-WALLED FROM A SINGLE STRIP

- Leakproof
- High thermal conductivity
- High bursting point
- High endurance limit
- Extra-strong
- Shock-resistant
- Ductile
- Lightweight
- Machines easily
- Takes plastic coating
- Takes plating
- Bright and clean
- No inside bead
- Uniform I.D., O.D.

Bundy Tubing Distributors and Representatives: *Bridgeport, Conn.:* Korhumel Steel & Aluminum Co., 117 E. Washington St. • *Cambridge 42, Mass.:* Austin-Hastings Co., Inc., 226 Binney St. *Chattanooga 2, Tenn.:* Peirson-Deakins Co., 823-824 Chattanooga Bank Bldg. • *Chicago 32, Ill.:* Lapham-Hickey Co., 3333 W. 47th Place • *Elizabeth, New Jersey:* A. B. Murray Co., Inc., Post Office Box 476 • *Los Angeles 58, Calif.:* Tubesales, 5400 Alcoa Ave. • *Philadelphia 3, Penn.:* Rutan & Co., 1717 Sansom St. • *San Francisco 10, Calif.:* Pacific Metals Co., Ltd., 3100 19th St. • *Seattle 4, Wash.:* Eagle Metals Co., 4755 First Ave., South • *Toronto 5, Ontario, Canada:* Alloy Metal Sales, Ltd., 181 Fleet St., E.

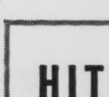
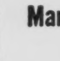
Bundyweld nickel and Monel tubing are sold by distributors of nickel and nickel alloys in principal cities.


"SHOT DOWN" to SAFETY

. . . at SUPERSONIC speed

with the help of PRECISION INVESTMENT CASTINGS by HITCHINER

EMERGENCY BAIL OUT!

And at sound-barrier speeds, a revolutionary bailout technique had to be found.

*So engineers at Stanley Aviation Corp., Buffalo, N.Y., developed an ejection seat that catapults **downward** from a plane and a lap belt that automatically opens, frees the airman from the seat, and sequences parachute opening.*

The cost of this priceless protection? Slashed to a minimum through the use of HITCHINER Precision Investment Castings. By combining several small parts into one . . . building complex shapes without added machining . . . using beryllium copper and stainless steel, HITCHINER achieved lower total production costs plus lighter weight with extra strength — economies and design achievements not possible with other production methods.

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tank. Prints are delivered at front or rear of machine and are stacked and collated at an adjustable receiving tray in front. Optional accessories include a rear stacking device and a constant-torque motor to take up long prints or roll stock. Made by Ozalid Div., **General Aniline & Film Corp.,** Johnson City, N. Y.

For more data circle MD-124, Page 237

Blueprint Pencil

Designed for checking and marking on all blue or white prints and coarse-tooth papers, Venus blueprint pencils are available in light blue, dark blue, green, yellow, red, vermillion, white and black. Specially formulated lead provides brilliant, insoluble contrasting color markings which are resistant to oil, dirt and grime and are also unaffected by sunlight and moisture. Lead, which does not reflect light, can be sharpened to a fine point and will not powder or smudge. Made by **American Lead Pencil Co.,** Hoboken, N. J.

For more data circle MD-125, Page 237

Tracing Cloth

Made from selected cotton fibers, a new pencil tracing cloth is designed for speedy drafting, sharp prints and long service. Having a fine surface, the cloth is made transparent by mechanical means rather than by the application of surface oils. Made by **Arkwright Finishing Co.,** Industrial Trust Bldg., Providence, R. I.

For more data circle MD-126, Page 237

COUPLINGS • BRAKES • DYNAMOMETERS • AJUSTO-SPEDE DRIVES •
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DYNAMATIC
EDDY-CURRENT ROTATING EQUIPMENT
DYNAMATIC DIVISION KENOSHA • WISCONSIN
EATON MANUFACTURING COMPANY
AUGUST 1954
BULLETIN GB2
Press Drives
Air Cooled Brakes
★ TYPICAL TYPES OF DYNAMATIC EDDY-CURRENT DRIVES
Ajusto-Spede Drives

Dynamatic Eddy-Current Units can be put to work in your plant or product

This Free Booklet Will Show You How

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Liquid Cooled Brakes
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Dynamatic eddy-current couplings, brakes, clutches, dynamometers, and Ajusto-Spede drives, in use today in practically every basic industry in both plant equipment and end products, are proving the ideal solution to difficult speed control and testing problems. Advantages include instantaneous response, infinitely adjustable speed control, wide speed range, quiet operation, low power loss, low maintenance cost, adjustable speed from an AC power source.

Our new booklet "Bulletin GB2" describes and illustrates the basic Dynamatic eddy-current units, including the new stationary field coupling. The text, augmented with illustrations and graphs, describes the basic eddy-current principles and drive characteristics. If you are interested in modern speed control, write for your copy of the new Dynamatic Bulletin GB2.

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EATON MANUFACTURING COMPANY

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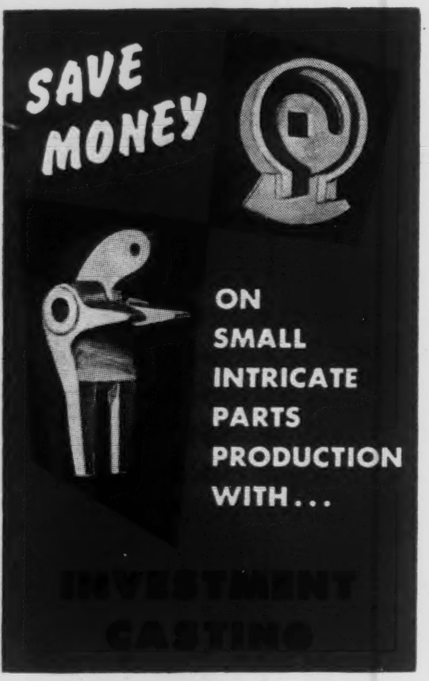

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- Cast parts with shapes too intricate to forge.
- Cast metals that are too hard for economical machining or finishing.

We are in a position to offer you assistance in planning your own investment casting department – or, we will gladly recommend casting firms that can handle the operation for you. This service will not obligate you in any way.

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This free 12-page booklet – "MODERN PRECISION INVESTMENT CASTING" – contains complete information on the Investment Casting Process.

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Precision Casting Equipment and Supplies
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WAtkins [illegible]

Stress Relief

GIVE him a subject, and J. P. Henderson can develop a cause with the zeal of a crusader. Here the question is to get or not to get

The Engineering Degree

What about this idea of going to engineering college? Maybe you have a son approaching that point of decision; or perhaps your friends and associates have boys in high school who ask you, as an engineer, about the pros and cons of an engineering education.

Whether or not to be an engineer is a big decision, and considerable material is available explaining the profession—all slanted for the high school student. But there is one kind of advice given to these youngsters which is of dubious value. Its a matter of the importance of an engineering degree.

Let's consider first the case where the money involved might represent a tight squeeze. And let's just imagine it's your own son who is involved.

Have you investigated every possibility? If you have all the facts and then decide it can't be done—too bad. Perhaps he can get training as a technician some way or another instead.

But if it's a borderline case and you decide against an engineering college training because "he can get along in engineering without it"—think again.

"Look," you tell me, "I'm working every day with men in the office and plant who are doing technical jobs and never went beyond high school, and besides they are probably making as much pay as graduate engineers. What's more I know several organizations in which top engineering is not college-trained either. All in all, I think my son can get into engineering without that degree."

This is a line of thought which I have heard quite frequently and for all of it I have one question. How old are these men you are talking about who apparently made a mark in engineering without college training? Aren't they all over fifty and most of them more nearly sixty? If so, there are several reasons *why they* could do it, and the most important ones are the conditions at the time they made their start. Back in the early 1900's the engineering college was doubtless proud of its course of study and considered it adequate to meet the industrial demands of the day. But aside from a few fundamentals its curriculum did not bear too much resemblance to that of the engineering college today.

Think of the technical advancements of the past 30 years—you don't need to have them listed for you. The point is that the clever, hard-working engineer today who is crowding sixty and never went to college saw the growth of these advancements and may have taken an active part in them with little handicap over his friend who graduated from college. The stuff they were dealing with was new to both of them. A little extra hard work on the part of the high school graduate put them both nearer an equal basis.

Since then there has been much water over the technical dam. Today the high school versus the engineering graduate are much farther apart in the extent and complexity of the knowledge to which the latter has been exposed.

And that's a real handicap to any one naive enough to think he can break into engineering without such training.

There is a second factor also. Regardless of interest and latent ability, few high school graduates will have the opportunity to break into an engineering job. An engineering executive, aware of the problems in his department, is almost certain to hire a technical man, rather than go through all of the painful training that would be required for the boy who never went beyond high school.

Don't kid yourself and don't kid your friends who have asked you for advice. It will be an extremely exceptional case if a boy gets anywhere in engineering in the future without an engineering degree.

THE ENGINEER'S Library

Recent Books

Introduction to Dynamics. *By L. A. Pars, fellow and lecturer in mathematics, Cambridge University; 523 pages, 5½ by 8½ inches, clothbound; published by Cambridge University Press, London and New York; available from* MACHINE DESIGN, $6.00 *postpaid.*

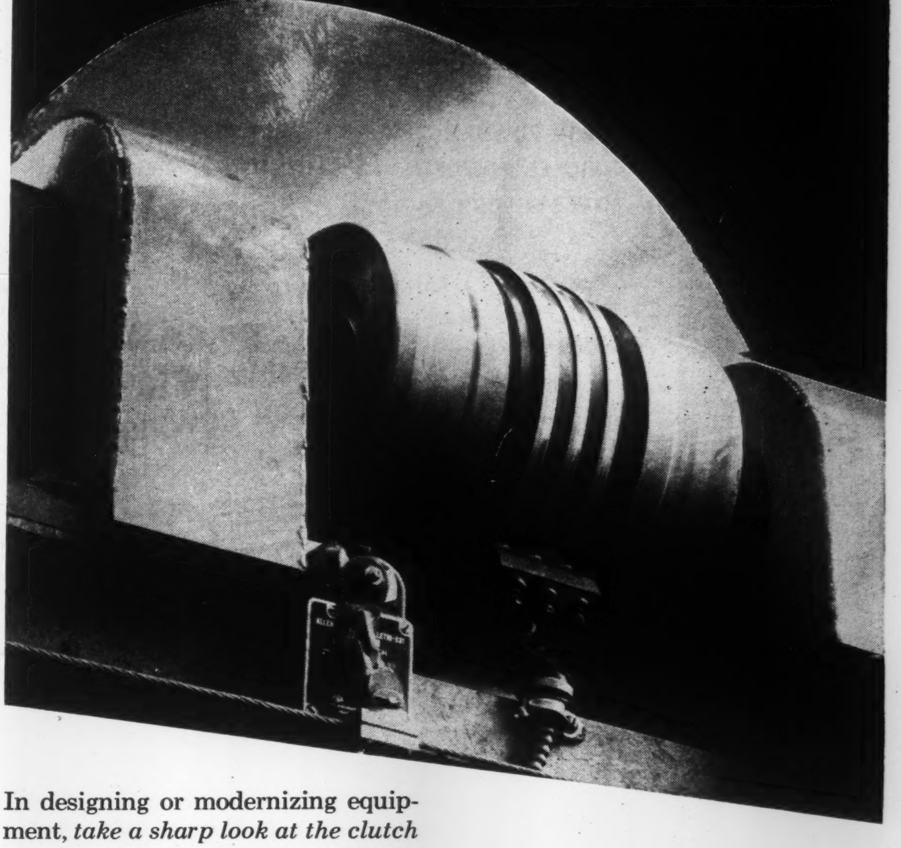
This textbook includes in its scope the study of motion of particles, rigid bodies and systems in two dimensions. It is intended as a general introduction to the subject in which use of calculus is essential. In 26 chapters this book covers scalar and vector calculations, Newtonian mechanics, motion on a straight line and in a field of force, variable mass, motion in a plane, the conservative field, constrained motion, free motion, central orbits, inverse-square law, forces on a rigid body, motion about a fixed axis, impulsive motion, momentum and dimensions.

◆

Alternating-Current Machines. *By A. F. Puchstein, consulting engineer, The Jeffrey Mfg. Co., Columbus, O.; T. C. Lloyd, chief engineer, Robbins and Myers Inc., Springfield, O.; and A. G. Conrad, professor of electrical engineering, chairman, department of electrical engineering, Yale University; 733 pages, 5¾ by 9 inches, clothbound; published by John Wiley & Sons Inc., New York; available from* MACHINE DESIGN, $8.50 *postpaid.*

Beginning with transformers, this textbook, a third edition, covers behavior and performance of the most important classes of ac power machinery. Fifty-four chapters are grouped in ten sections headed as follows: transformers, alternators, polyphase induction motors, single-phase induction motors, synchronous motors, alternators in parallel, synchronous converters, mercury-vapor rectifiers,

Stearns can help you cut costs—
IN THE CLUTCH



In designing or modernizing equipment, *take a sharp look at the clutch* — it's one key spot where you can hit high operating costs.

And you can hit these costs hard with a matched-to-the-machine Stearns magnetic clutch or clutch-brake combination. Here's why:

In addition to Stearns wide range of standard models, Stearns will custom-build clutches to fit your machine exactly — no makeshifts, no "almost rights." Stearns clutches provide split-second engagement or disengagement—help machines hold close tolerances.

Make these Stearns advantages work for you:

WIDE TORQUE RANGE — .4 to 30,000 lb foot. Handles everything from business machines to steel mill screwdowns and ball and rod mill drives.

LOW INERTIA — Fast, smooth engagement and disengagement.

VARIED DESIGNS — Through shaft, split shaft, duplex for two-speed drives, forward and reverse drives — other special applications.

WIDELY ADAPTABLE — DC or AC with rectifier. Automatic and remote control. Operates in conjunction with electronic circuits.

QUIET AND COOL RUNNING — Generous friction surface area and low unit pressure.

EASY WEAR ADJUSTMENT — Provides longer clutch life.

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For full details consult your 1954 Sweet's Product Design file or write for Bulletin 226-C-4. 1095

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single-phase commutator motors and repulsion motors. New material inludes information on adjustable-speed drives.

◆

Introductory Circuit Theory. *By Ernst A. Guillemin, professor of electrical communication, Massachusetts Institute of Technology;* 576 *pages,* 6 *by* 9 *inches, clothbound; published by John Wiley & Sons Inc., New York; available from* MACHINE DESIGN, $8.50 *postpaid.*

Beginning with first principles, this textbook provides an introductory treatment of methods of steady-state and transient circuit analysis. It also gives basic concepts essential to synthesis procedures. It is intended to meet the needs of flexibility and nonconventionality set by recent trends in industrial and technological activities. Graphical interpretations and computational aids essential to research in network theory are included.

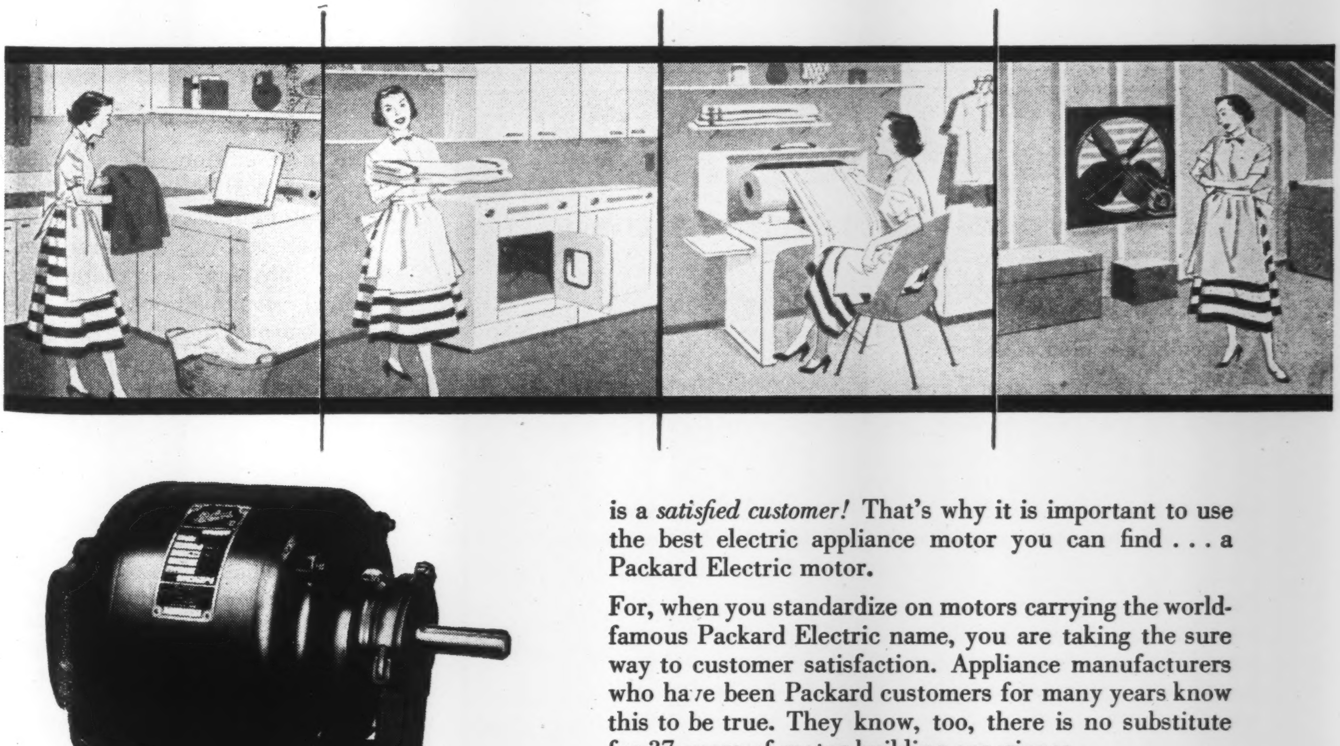
Subjects covered in the ten chapters include: network geometry and variables; equilibrium equations; methods of solution; circuit elements and source functions; impulse and step-function response of simple circuits; behavior of simple circuits, energy and power, and more general networks in the sinusoidal steady state; steady-state and transient behavior of lumped linear circuits; and generalization of circuit equations and energy relations.

◆

Elementary Tool Design. *By Elmer B. Benson, gage design engineer, Rock Island Arsenal;* 224 *pages,* 6¾ *by* 9¾ *inches, clothbound; published by Chas. A. Bennett Co. Inc., Peoria, Ill.; available from* MACHINE DESIGN, $4.76 *postpaid.*

Although intended primarily for a preparatory course in tool engineering and designing, this book contains much information of use to machine designers. Eighteen chapters discuss jig design, gages, fixtures and dies, with related information on shop practice and special skills. Appendixes include

THE MOST IMPORTANT FACTOR IN YOUR BUSINESS...



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For, when you standardize on motors carrying the world-famous Packard Electric name, you are taking the sure way to customer satisfaction. Appliance manufacturers who have been Packard customers for many years know this to be true. They know, too, there is no substitute for 37 years of motor-building experience.

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The Case of the

TRANSMITTIN' MITTEN

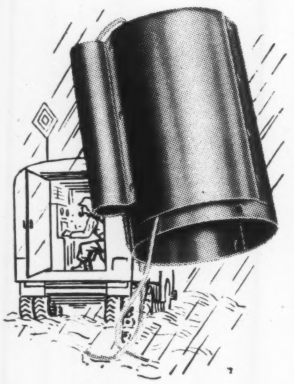
Solved by WATLOW ELECTRIC HEAT

CASE

Because Army radio transmitting equipment is exposed to weather extremes, and because the oscillator must warm up before the unit can operate, Watlow was called in to design a heating device to keep the oscillator warmed up and ready to operate without temperature lag.

SOLUTION

The result was the metal "mitten" shown here. It fits over the oscillator, is made of 2¾" O.D. by 4½" long extruded aluminum, and carries a 26½ v.—50 w. Watlow Heating Unit on its surface. Now, even in sub-zero weather, transmission is unaffected by temperature lag.



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A basically new idea in balancing for precision, easy set-up and easy adaptability for any balancing problem.

Does both kinetic and dynamic balancing with average set-up time of less than three minutes. Capacity from half a pound to half a ton and ½" to 44" dia. Sensitivity is within 0.04 in.-oz. Model 704, price including operator training, only $3475. Other models available with greater capacities, etc.

Write for more information

Dynamic balancing a dog food chopper on a Stewart-Warner 704 Electronic Balancer.

Merrill ENGINEERING LABORATORIES

definitions; tables on taps, bolts, nuts, tapers, shanks, sockets; formulas; symbols; and standard government drawing abbreviations.

Association Publications

Proceedings of Engineering Graphics Conference. 90 *pages,* 6 *by* 9 *inches, paperbound; available from Engineering Experiment Station, Purdue University, Lafayette, Ind.,* 50 *cents per copy.*

This bulletin includes papers on delineations, analagous representation, problem solutions, computing devices and reproduction processes, presented at a conference held at Purdue University, November 20, 1953.

Manufacturers' Publications

Aluminum Data Book. 220 *pages,* 5½ *by* 8¾ *inches, ringbound, paper covered; available from Reynolds Metals Company, Desk PR,* 2500 *South Third St., Louisville* 1, *Ky., on company letterhead request.*

This new edition offers detailed data on properties and characteristics of aluminum, including information on alloys, tempers, sizes, shapes, physical characteristics, chemical compositions and mechanical properties. An introductory section discusses production and processing of aluminum and aluminum alloys.

Government Publications

NACA Technical Series. *Each publication is* 8 *by* 10½ *inches, paperbound, side-stapled; copies available from National Advisory Committee for Aeronautics,* 1924 *F St. N.W., Washington* 25, *D. C.*

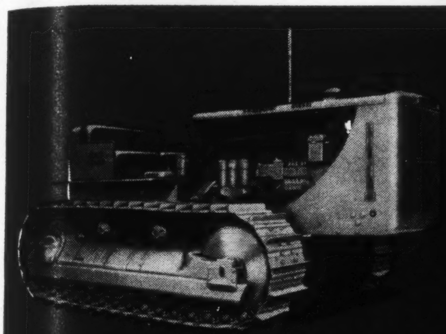
The following Technical Notes are available:

3197. **Mechanical Properties at Room Temperature of Four Cermets of Titanium Carbide with Nickel Binder**—22 pages.

3199. **Stress Distributions Caused by Three Types of Loading on a Circular Semimonocoque Cylinder with Flexible Rings**—54 pages.

3206. **Torsional Vibrations of Hollow Thin-Walled Cylindrical Beams**—33 pages.

3231. **Bending Tests on Box Beams Having Solid- And Open-Construction Webs**—25 pages.



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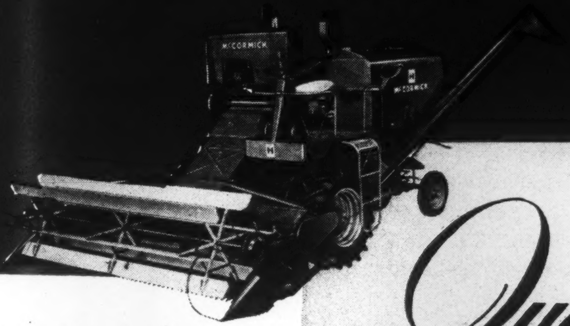
Ford T-800 Tandem Axle Big Job with [illegible] V-8 engine.



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The Palmetto G-T Ring, unlike an O-Ring, will not twist and turn in the groove. T-form prevents spiral failure even in dynamic applications.

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Resilient "T"-section supported by non-extrusion rings on either side makes extrusion impossible. As pressure is applied, non-extrusion rings are urged against cylinder wall, blocking the path of extrusion.

Write for our Manual MP-200, Engineering Standards for Palmetto Molded Packings. For design information on G-T Rings, see our catalog in Sweet's Product Design File.

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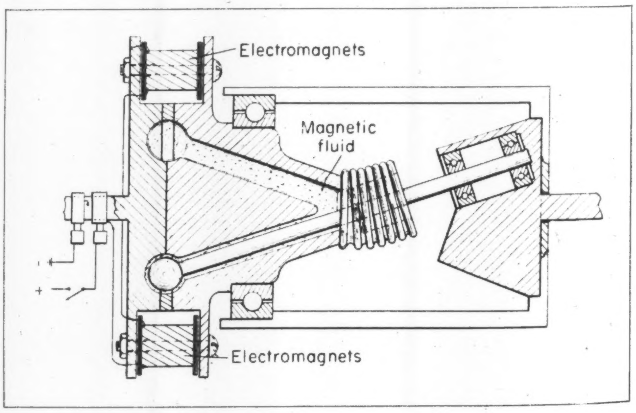
N O T E W O R T H Y

Patents

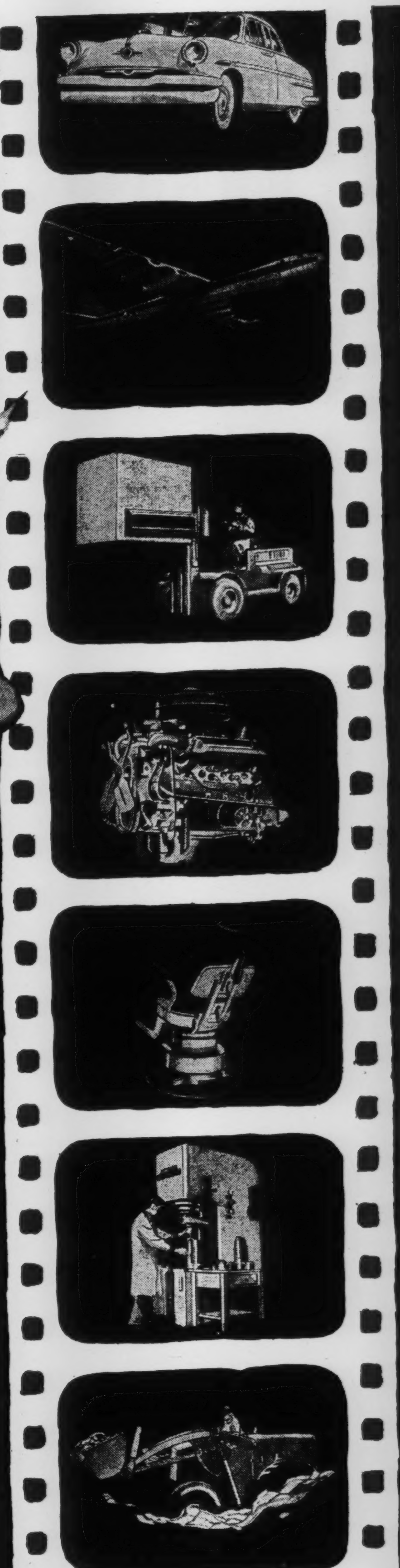
LEAKTIGHT SEALING of moving members with a circular shape is provided by a combination seal unit which employs a standard O ring and a flat, soft rubber ring. Mounted in the retaining groove between the O ring and the bottom of the groove, the soft rubber ring serves as a cushion, to take up deformation of the seal under load and maintain the circular shape of the O ring. Area of the contact surfaces is thus minimized, reducing sealing friction. The design is especially suitable to nonconcentric or out-of-round parts. *Patent* 2,661,967 *assigned to MBG Corp. by W. F. Mitchell.*

HERMETIC SEALING of pivoted control rods is accomplished with a stationary bellows seal. Applied to a wobble rod used to actuate a rotary valve, the seal permits both angular and rotary motions of the rod and eliminates relative movements at the sealing surfaces. The seal assembly consists of a standard metal bellows soldered at one end to the rod and at the other end to the casing. Movements of the rod are accommodated by flexing of the convolutions of the bellows, preventing undue strain on the soldered joints and maintaining sealing effectiveness in all rod positions. *Patent* 2,659,569 *assigned to A. P. Controls Corp. by E. C. Ehlke.*



AUTOMATIC SPEED CONTROL in instrument drives is provided by a reduction gear unit which varies the drive ratio in response to direction of rota-

hydraulic power



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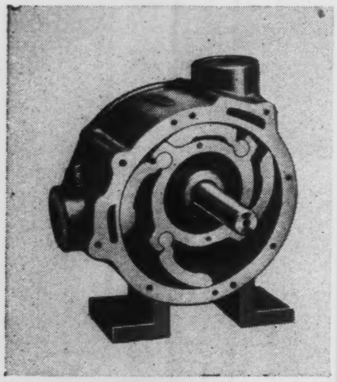
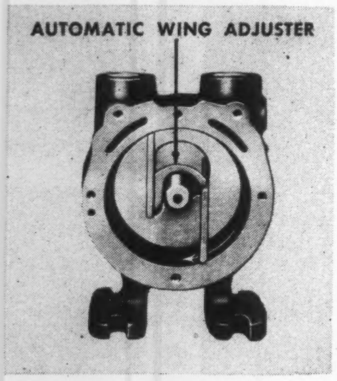
"We've had a Leiman pump in almost continous operation, 24 hours a day, for the last 21 years. It's as nearly noiseless as a pump can be . . . absolutely reliable in every respect."



4-WING TYPE

Vacuums to 20"; pressures to 15 lbs.; displacement to 162 cfm. Wings hinged to piston—centrifugal force maintains close, continuous contact to cylinder wall. Wings take up their own wear, insure positive pressure or vacuum. No composition material to require frequent renewal. Air chamber is large because of small piston size, giving unmatched capacity for size and weight of pump.



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Vacuums to 29.9"; pressures to 25 lbs.; displacement to 40.8 cfm. Blades cannot stick, because of exclusive Leiman automatic wing adjusting lever which forces each blade to meet cylinder wall, insures positive pressure or vacuum. Only steel blades (no composition) are used. They take up their own wear, deliver years of trouble-free service.

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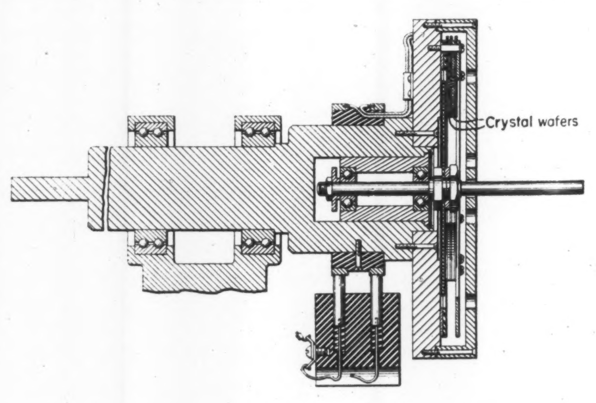
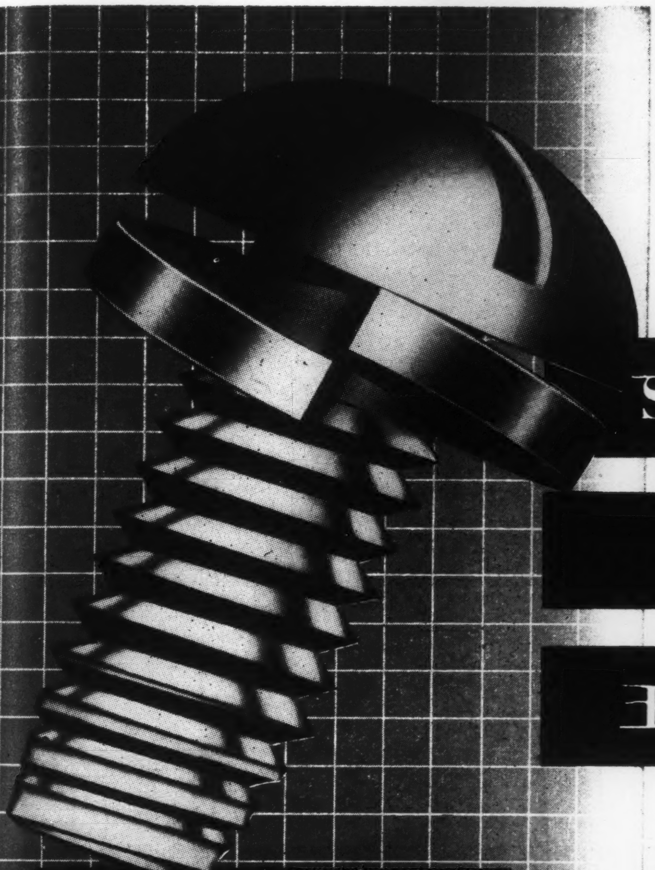
tion. Controlled through a roller and cam arrangement, the reduction unit employs a planetary gear set in combination with a pin and lug drive. With the drive gear rotating in one direction, a lug which is located on the drive gear engages a pin on the driven member to provide direct drive. Reversal of the direction of rotation of the drive gear disengages the lug and pin drive and actuates the roller and cam mechanism to lock in the planetary gear set, providing a reduction in output speed. After a predetermined angle of rotation at reduced speed, a cam follower unlocks the planetary gear set and the lug and pin reengage for direct drive. Applied to instrument drives, the design is particularly suited for adjustment operations, providing a normal high-speed traverse with a slower rate for fine adjustment over a limited range. *Patent 2,662,422 assigned to Collins Radio Co. by H. S. McGowan.*

CRYSTAL CLUTCH for small mechanisms utilizes piezo-electric wafers to obtain high-speed control response. Sandwiched between two electrodes, the wafer crystals are mounted in groups on either the driving or driven clutch disk. Electrical energy is supplied to the crystals through slip rings. When energized, the crystals distort and bend due to the piezo-electric effect, driving the two clutch plates into frictional engagement. Since only a low operating current is required for clutch actuation, starting of computer mechanisms, such as tape transport mechanisms, can be readily controlled by electronic methods. *Patent 2,666,512 assigned to United States of America by E. O. Codier.*



VIBRATIONLESS COUPLING of rotating shafts is achieved through a centrifugally operated friction drive. Weighted arms pivoted around the drive shaft



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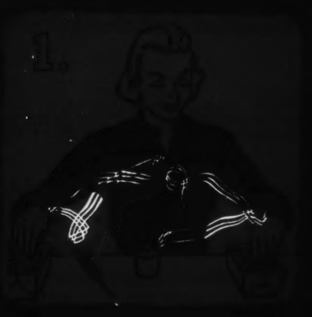
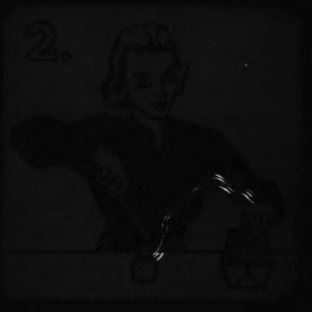
The reason for this saving lies in the one piece design of these Reliance fasteners. By making the lock washer an integral part of the bolt, yet free to rotate and function, production workers eliminate the steps of picking up a lock washer, slipping it in place and holding it until the piece is fastened. Production costs are definitely affected . . . for the better.

In addition, Reliance Springtites and Sems are easier to use in "hard-to-get-at" places, they are less apt to get lost and they offer an inventory that is automatically balanced... 1 lock washer and 1 bolt equal one Springtite or Sem.

Engineering bulletin S-49 will give you more complete details. Write for a copy and it's yours. No obligation.



THIS IS WASTE MOTION



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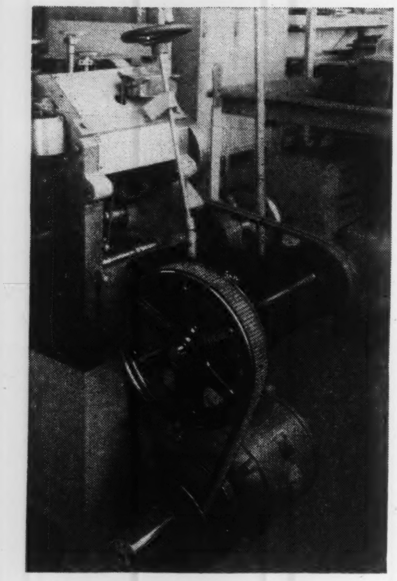

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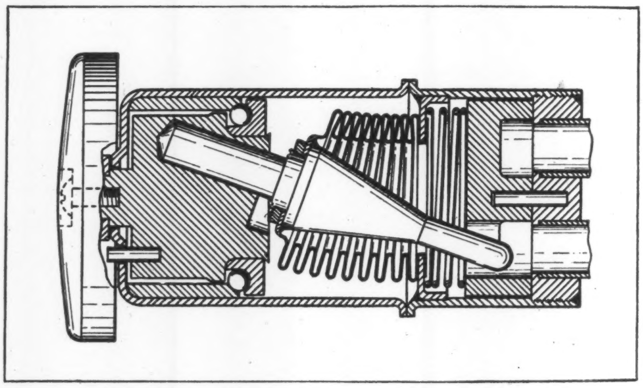
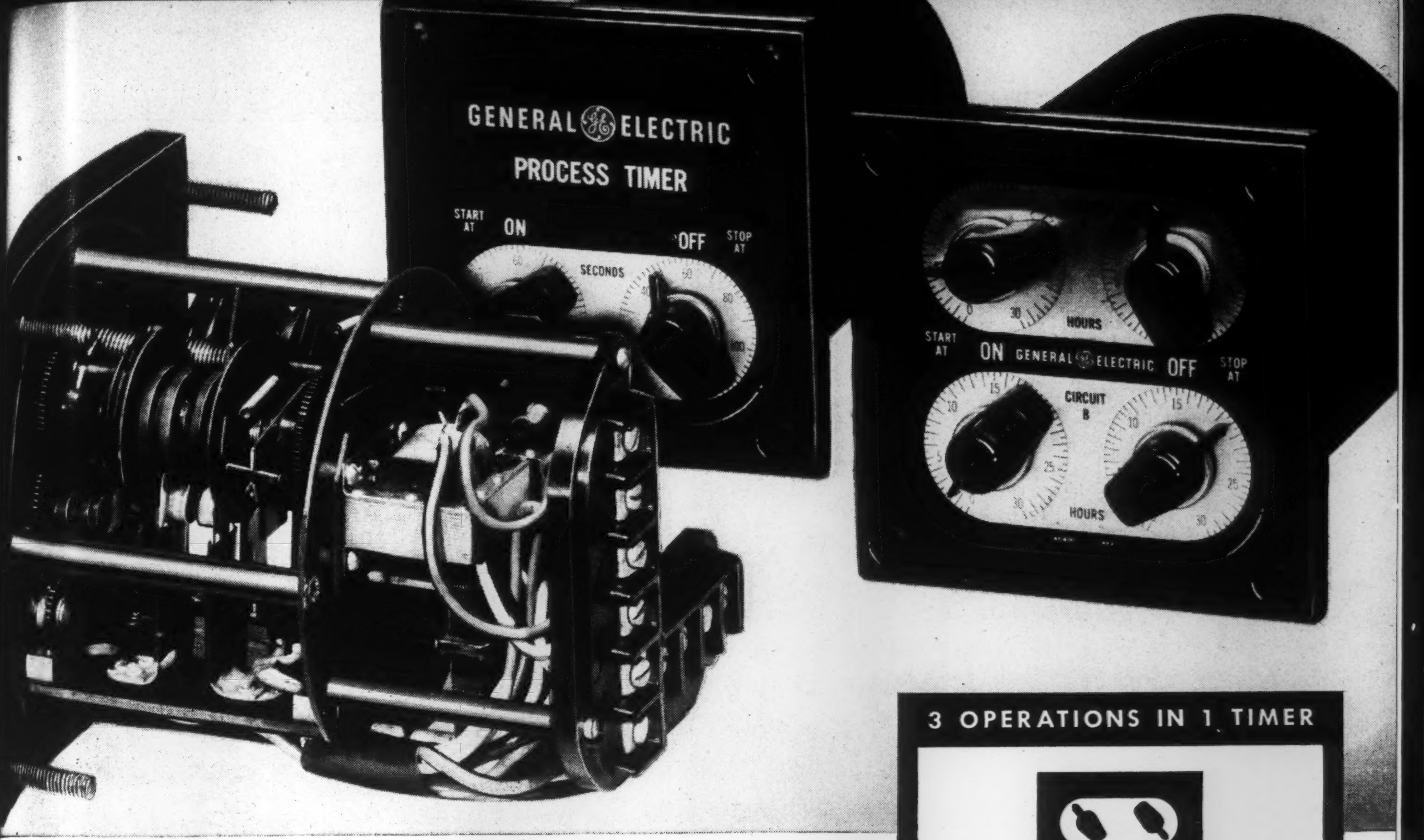
bear against inside concave surfaces of a driven gear. As rotational speed increases, torque-carrying capacity increases due to increased pressure of the weighted arms against the curved surfaces. Sudden vibrational shocks are absorbed by sliding action between the arms and the driven gear, while torque-carrying capacity at constant speeds remains the same. *Patent 2,667,049 assigned to General Motors Corp. by R. W. Guernsey and R. C. Ulrey.*

WOBBLE-ROD CLUTCH employs magnetic fluid as the clutching medium. "Freezing" of the magnetic fluid by an external magnetic field connects the wobble-rod to one rotating element. The other end of the rod is fixed to the other clutch element. Electromagnets supply the actuating magnetic field. Leakage is prevented by a fixed bellows seal which confines the magnetic fluid inside one rotating element. Since the magnetic fluid does not contact the bearings, there is no bearing wear from iron particles. *Patent 2,665,789 assigned to Minneapolis-Honeywell Regulator Co. by W. H. Ingersoll.*



LEAKTIGHT SEALING of fluid-clutch shafts is accomplished with an annularly grooved steel ring rotating against a nylon sealing surface. Rotation of the steel ring gradually cuts mating grooves into the nylon seat increasing the effectiveness of the sealing engagement. Spring-loading of the steel ring insures a tight fit and takes up wear. The seal is especially suitable for use with abrasive fluids. *Patent 2,668,068 assigned to Norden Laboratories Corp. by H. Bredemeier.*

AUTOMATIC OVERLOAD prevention for rotating shafts is obtained with a clutch employing radial drive rollers. The rollers are mounted on a spring-



NEW G-E TIMER

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The new General Electric TSA-18 process timer, available in single- and double-circuit models, reduces your need for expensive, custom-built timing equipment. Its adaptability enables it to meet, with precise and dependable operation, the majority of your timing-equipment requirements.

THREE TYPES OF CONTROL are available in the TSA-18. At no extra cost this new process timer is capable of being connected for manual start and reset, automatic reset, and automatic reset and repeat operations.

ADJUSTABLE "ON"-"OFF" TIME setting is provided in this new timer. The TSA-18 will begin and end a process at any specified time. Load circuits can be easily adjusted to close or open at any point within this cycle. This feature enables you to reduce the multiple number of timers usually required to perform these timing operations.

HEAVY-DUTY CONSTRUCTION of the TSA-18 reduces maintenance and repair costs and provides long life. Nylon gears, permanently lubricated Telechron* motor, hardened steel parts, and 1/16-inch solid silver-face contacts contribute to the new timer's long life.

FOR MORE INFORMATION call your nearest General Electric Apparatus Sales Office, or write for Bulletin GEC-1223 to Section 603-179, General Electric Co., Schenectady 5, New York.

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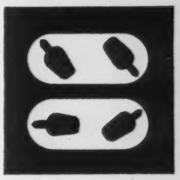
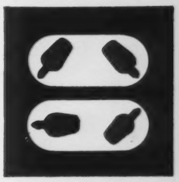
3 OPERATIONS IN 1 TIMER



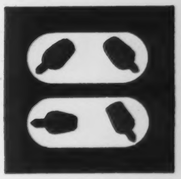
MANUAL OPERATION

Timer is started and reset manually from an external switch. Two adjustable load circuits independent of each other are available with this type of operation.



SEMI-AUTOMATIC OPERATION

Timer is started from external switch. Circuit "A" resets time at the end of the adjustable cycle. Circuit "B" opens and closes load circuit within the cycle.



AUTOMATIC OPERATION

Circuit "A" starts and repeats the cycle for continuous operation. Circuit "B" opens and closes load circuit at any point within the cycle.

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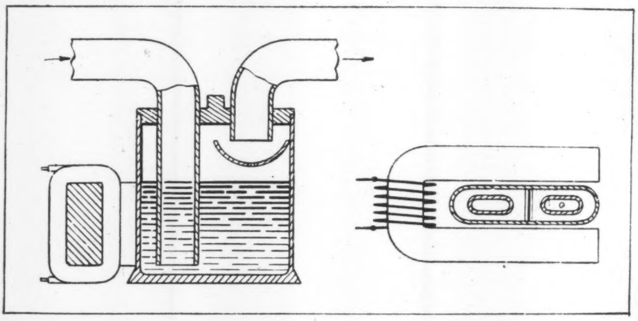
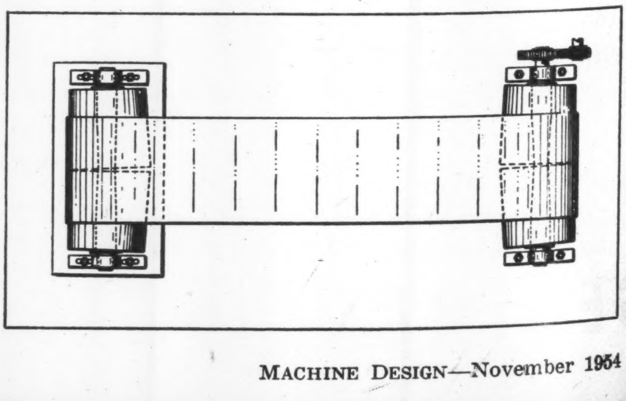
loaded driving disk and engage mating grooves in the driven disk. An overload on the driven shaft causes the rollers to ride out of the grooves and momentarily disengage the clutch. Spring pressure can be adjusted to vary the overload point. Designed for low-speed operation, the clutch may be modified to operate a switch, turning off the drive motor when disengagement occurs. *Patent* 2,667,050 *assigned to Mechanical Handling Systems, Inc. by P. Klamp.*

FLUID FLOW CONTROL is accomplished by passing liquid or gas through a tank filled with an electromagnetic fluid solution. Rate of flow is controlled by the amount of stiffness imparted to the magnetic solution by an external magnetic field. Baffles prevent extreme agitation of the fluid. *Patent* 2,670,749 *assigned to Hanovia Chemical and Mfg. Co. by E. Germer.*



AUTOMATIC BELT CENTERING of metal belts for power or conveyor service is achieved with a resiliently mounted, split, crowned pulley. Centering forces between the pulley and the belt are the result of the inward tilting of the pulley halves by the belt. Greater compression of the resilient mounting material at the crowned center of the pulley produces greater pressure against the center of the belt, tending to keep it aligned. *Patent* 2,665,592 *assigned to U. S. Steel Corp. by E. T. Lorig.*



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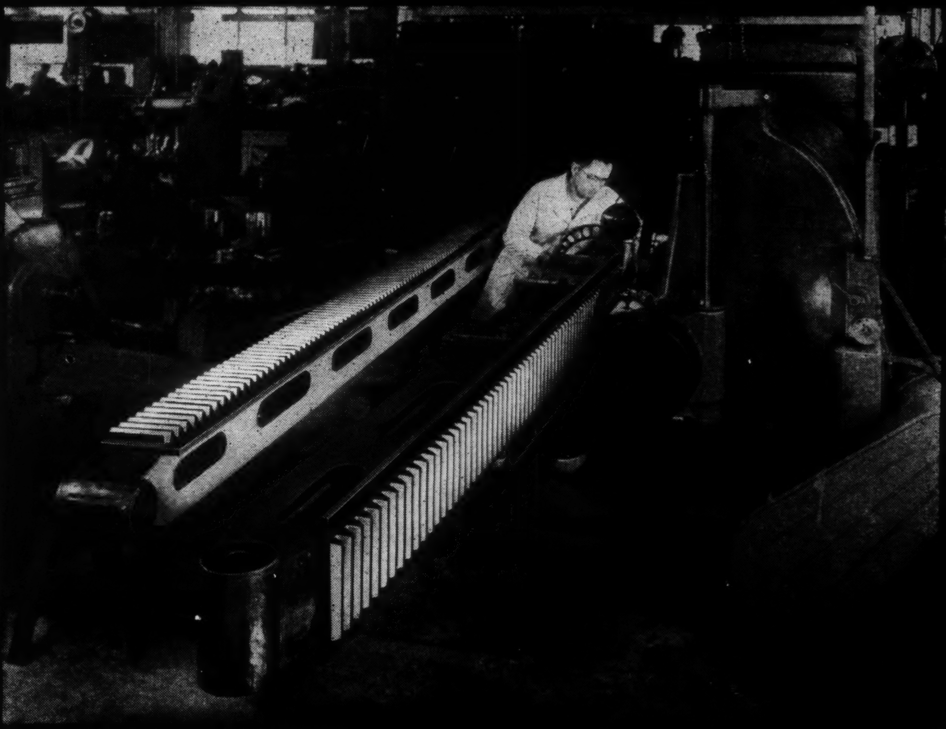

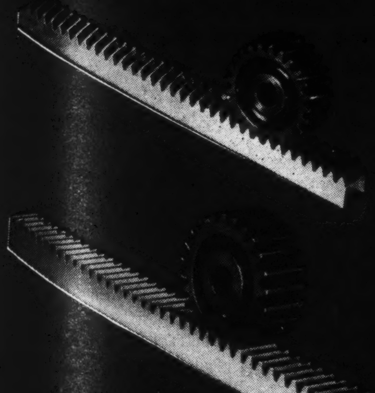

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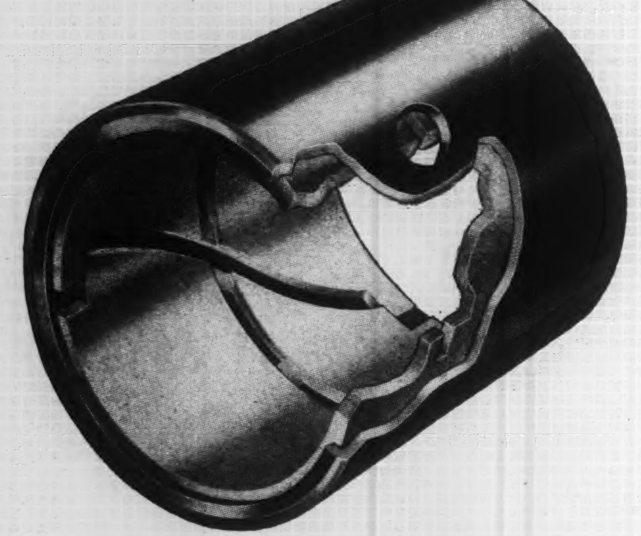

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Heating

Horizontal Unit Heaters: Series of horizontal unit heaters for use with high-pressure, high-temperature steam systems provides low outlet temperatures. Heaters can be operated on steam pressures up to 125 psi. Capacities of units range from 385 to 5430 cfm of air at 70 F, 17,400 to 228,000 Btu per hour (60 F entering air and 2 psi steam pressure). Units are also suitable, without modification, for forced hot water heating systems. Heaters are available with single or two-speed totally-enclosed motors. Casings have horizontal directional louvers; vertical deflection louvers are available. *American Air Filter Co., Louisville, Ky.*

Heater: Model VO, a 168,000 Btu heat machine, operates from a detached fuel supply, using regular furnace type fuel oil, kerosene or 100 per cent catalytic-cracked oil. Burner is Underwriters' approved gun type, pressure atomizing. Controls consist of a stack switch, fan limit switch and master switch. Stack switch shuts off the oil burner if oil does not ignite within 90 seconds after it is first sprayed on the burner. This switch must be reset manually before the burner can be restarted. Fan limit switch controls the blower which is located on top the machine and also serves as a safety switch, automatically holding temperatures between prefixed limits and preventing overheating. Master switch cuts off all controls and motors and operates manually. Design of stack facilitates attachment of an outside vent, permitting use of the machine in confined areas. If used without a vent or flue, machine directs preheated air back into the blower where it is reheated. Dimensions of the machine are 21 x 33 x 69; weight is 345 lb. *Fageol Heat Machine Div., R. D. Fageol Co., Kent, O.*

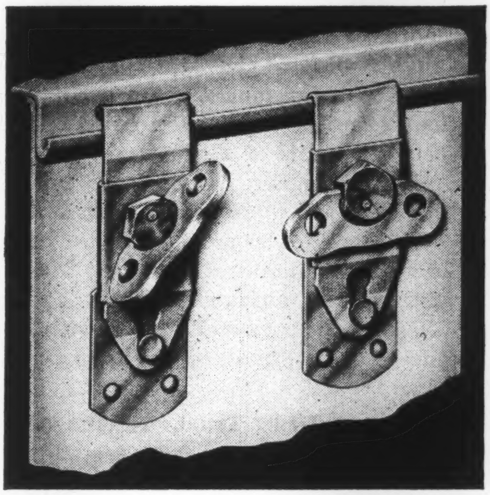
Steam Unit Heaters: Available in 16 horizontal and 12 vertical types, line of steam heater meets wide range of heating needs in factories, stores and offices. A model without fins is designed for use in textile plants. Side entrance on horizontal models provides four different pipe connection arrangements, each permitting maximum headroom. Louver arrangement assures efficient heat flow. All models are equipped with totally-enclosed motors to drive the propeller fans. *Ilg Electric Ventilating Co., Chicago, Ill.*

Materials Handling

Crane Truck: For transporting hard-to-manage loads in confined areas, and to permit reaching into normally inaccessible areas, a new 6000-lb capacity crane truck has slewing, or swinging, action to facilitate handling on either side of the travel area with-

Have you a similar fastening problem?

File: Simmons LINK-LOCK



When the armed forces needed a positive, high-strength fastening device for instrument housings, transit cases, and storage boxes, Simmons developed LINK-LOCK. This *brand-new* device doesn't use springs, yet works with fingertip pressure through a unique mechanical arrangement: the vertical sliding latch is moved in and out of locking position by a disc rotated with a wing nut. The fastener is immune to low temperatures, is easy to operate even with arctic mittens, furnishes up to 450-lb. pull-down pressure. Open or closed, it lies flat against the side of the case it fastens.

LINK-LOCK may be the answer to your fastening problem. If your design involves heavy fastening pressures, watertight sealing, high strength, resistance to impact, ask about LINK-LOCK. Simmons can furnish it with special engagement-latch details, or for operation by bolt or screwhead instead of wing nut. Write for LINK-LOCK DATA SHEET today. It gives complete details and dimensions. A Simmons engineer will be glad to work with you on your fastening problems.

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Mac-it heat-treatment is more than a mere case hardening or surface processing. The high quality of Mac-it Special Alloy Steel adapts it to heat-treatment that penetrates throughout the structure of the screw so that the center possesses the same sturdy toughness possessed by the outside. Proved formulas govern this process.

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out additional movement. A separate motor drives a grooved drum through worm and planetary gears and an electric limit switch stops travel at the extreme limits of slew motion. Crane has travel speed of 4 mph without load, 3½ mph with full load. Hoisting speeds are 28 fpm without load, 14 fpm with full load. Lowering speeds are 15 fpm without load, 26 fpm with full load. In telescoped position, boom measures 12 ft, 6 in.; extended, it is 19 ft, 2 in. Boom lengths may be varied to suit specific operating requirements. Many types of attachments are available including a magnet which receives its power from the battery, or from a gas or diesel-electric generating unit. *Elwell-Parker Electric Co., Cleveland, O.*

Platform Type Electric Lift: Rapistan VL vertical-lift electric platform hoist moves goods vertically between floors, or from one elevation to another. It is now available with a platform for use on one floor level, with a cab for mounting in a hoistway for between-floors use, or equipped to lift and lower materials between levels of a gravity or power conveyor system. Electric hoist mounted at top of unit is totally enclosed and equipped with limit switches for safety. Wide range of models with carriage travel up to 20 ft is available. Upper and lower limits of platform travel are adjustable. Units are made with either 250 or 500-lb capacity, and with a choice of lift speeds. *Rapids-Standard Co. Inc., Grand Rapids, Mich.*

Battery-Powered Lift Truck: New model Power Ox is operated by riding driver from a standing position. Located in the steering handle are forward and reverse pushbutton controls and dual trigger hand-operated brake controls for operation with either hand. Automatic speed acceleration is provided, with four speeds forward and three reverse. Truck has speeds up to 6 mph with no load and 3½ mph with load. Power for operation is from a 24-v battery. Truck is built in standard capacities of 4000 and 6000 lb. *Barrett-Cravens Co., Northbrook, Ill.*

Pallet Truck: Compact and lightweight for use with low floor capacities and elevators, RP-4 electric, rider type pallet truck handles loads up to 4000 lb. Pallet for lift is 4 in., and lifting time is approximately 5 seconds for full lift with full load. Overall spread of the pallet forks is available in standard widths of 25, 27, 30 and 36 in. Fork lengths of 36 to 60 in. are available in increments of 6 in. Designed for operation in 5 and 6-ft aisles, truck has three speeds forward and three reverse with time delay controls insuring smooth acceleration between speeds. Travel speed with no load is 5¼ mph; with full load, 4 mph. Spring-loaded dual caster wheels assure four-point contact of truck on uneven floors. Drive unit is a totally-enclosed double-reduction spur gear drive connected direct to drive axle. Gear train operates in an oil bath with all rotating parts mounted on ball bearings. *Yale & Towne Mfg. Co., Philadelphia, Pa.*

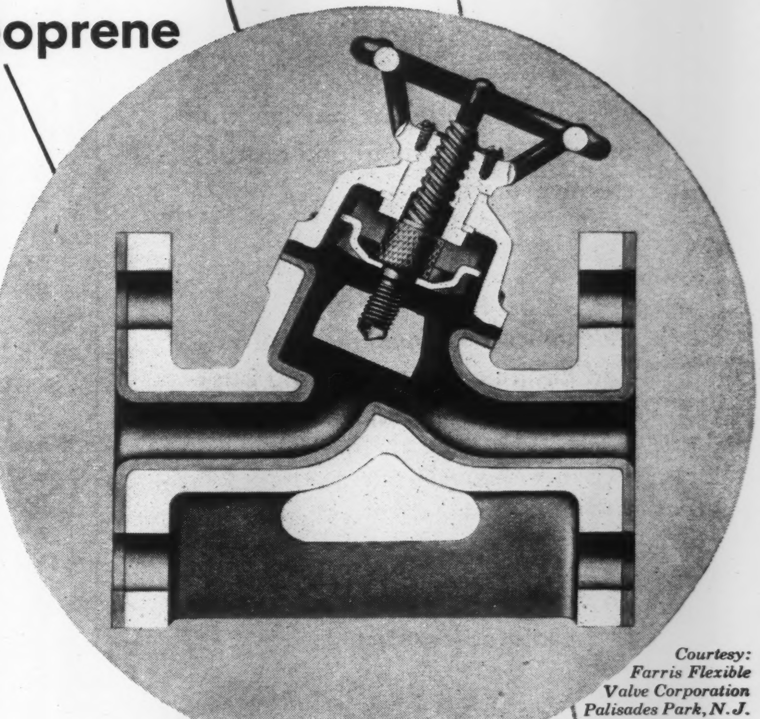
Vibratory Feeder: Model F-86 vibratory feeder has a 54 x 72-in. flat pan trough with feeding capacity of 750 tons per hour of bulk materials. Electro-

FLEXIBILITY

CHEMICAL RESISTANCE

ABRASION RESISTANCE

These properties of neoprene make a better DIAPHRAGM VALVE


Courtesy: Farris Flexible Valve Corporation Palisades Park, N. J.

Designers made this valve doubly effective for abrasive, corrosive or vacuum services. For, unlike ordinary diaphragm valves, it has *two* separate elements for the jobs of sealing and seating. A flexible neoprene diaphragm seals off the valve's upper mechanism, while a replaceable seating disk surfaced with neoprene gives positive closure—*independent* of the diaphragm.

The neoprene diaphragm retains its flexibility even when exposed to oil and grease or corrosive chemicals in the line. And since this design does not subject the diaphragm to seat wear, it stays intact to perform its sealing function through a longer service life. The replaceable seating disk is surfaced with ample thickness of neoprene for closure over fine grits. And the neoprene resists abrasion and corrosion . . . has the lasting resilience required for a tight seal.

Frequently the entire valve is lined with neoprene when severe chemical service is expected. This liberal use of Du Pont neoprene offers further proof of the confidence designers have in the balanced combination of properties which neoprene offers . . . to make a better design or to develop an entirely new solution to a problem.

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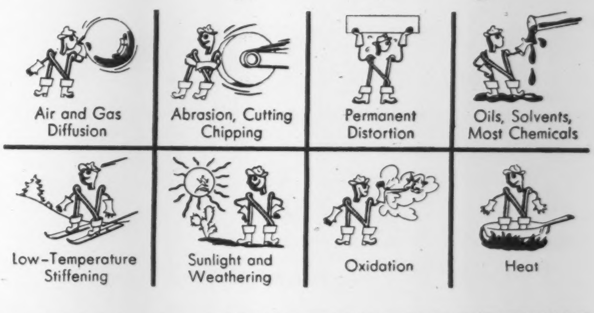
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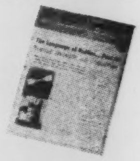

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magnetic principle of operation eliminates such rotating parts as gear, belts, idlers, and eccentrics and produces 3600 conveying vibrations per minute from 220 or 440-v, 60-cycle ac. Power consumption at 220 v is 3000 w; current input is 45 amp. Rate of material flow out of the feeder is regulated by a dial switch in a separate control box. *Syntron Co., Homer City, Pa.*

Fork Lift Trucks: Two gasoline-powered fork lift trucks have electric transmissions which make possible a full day's operation on 5 gal of gasoline. Model FD 50 is rated for loads up to 5000 lb; model FD 60, for loads up to 6000 lb. Design of both trucks includes worm-gear power axle drive which provides high efficiency under heavy loads when maximum power is needed; worm gearing achieves the required speed regulation in one step. Inching control is incorporated for high-speed hoisting at low travel speeds; foot pedal movement controls resistance in the generator shunt field, causing reduction in voltage to the drive motor. Variable-voltage dc generator integral with the engine generates power for series motor mounted on power axle. *Baker-Raulang Co., Cleveland, O.*

Battery-Powered Pallet Stacker: Originally designed to plug into an electrical outlet, pallet stacker is now available with a 12-v, battery-operated lifting motor and automatic, built-in charger. Two 6-v, 125 amp-hr batteries are wired in series to provide the 12-v current. With capacity to lift and stack 2000-lb pallet loads, unit has adjustable-base forks that will straddle all popular size pallets. Lifting forks are also adjustable in width and can be furnished in lengths of 36 or 40 in. Stacker is positioned manually and has a steering arrangement which provides good maneuverability. *Raymond Corp., Greene, N. Y.*

Metalworking

Centerless Grinder: Model 20 centerless grinder made by Herminghausen Works in Germany has simplified control system, facilitating setup and operation. Tapered work can be performed by both infeed and throughfeed methods. Work capacity is from 1/32 to 1¼ in. diameter. Unit can operate as a throughfeed, infeed, crushed form, thread or template form grinder. Grinding wheel is powered by a 5-hp motor. Quiet and cool-running multi-unit, plain bearings on the grinding and control wheel spindle are pressure lubricated. These two high-precision main bearings make machine capable of producing highly accurate work and fine finishes. Coolant is fed by a separate motor-driven pump through a filter. *American Herforder Corp., Chicago, Ill.*

Punch Presses: Models 4R and 5R Rigid Rib presses, designed for deep-throat punching, have large die space area. Four-ton model has a 55-lb roller bearing-mounted flywheel. Five-ton model operates at speeds variable from 90 to 285 rpm and has a 130-lb, 18-in. diameter flywheel mounted on double roller bearings. Presses have a positive single trip as standard equipment and can be converted instantly to continuous

The Fitting that Never Gets Tired of Absorbing Shocks and Vibration!

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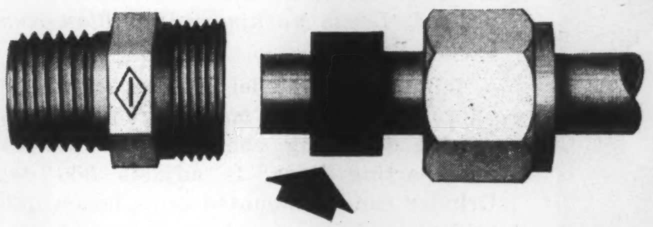

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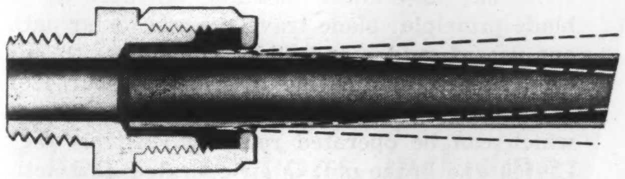
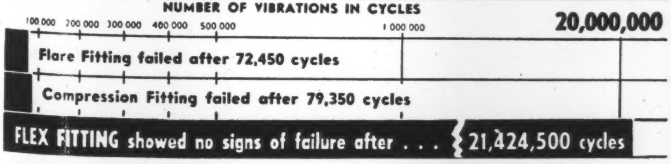


The Flex Fitting actually permits the tube to flex back and forth through angle shown. Note that tubing is cushioned against any damage.

Comparative Vibration Test Results

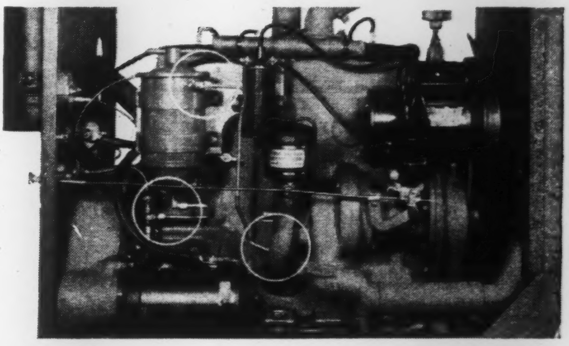


On vibration tests, where other fittings failed quickly, Flex Fittings withstood over 20,000,000 cycles without sign of failure.

FLEX FITTINGS make safer joints that are virtually indestructible by vibration . . . absorb shock and minor tube movement . . . assure a positive pressure-tight seal.

FLEX FITTINGS are very easy to install . . . simply slip nut and Flex sleeve over tubing . . . insert tubing into body and tighten nut — that's all!

FLEX FITTINGS can be used with all kinds of tubing



If you have a tough tubing connection job that involves vibration, shock or tube movement, it will pay you to consider IMPERIAL FLEX FITTINGS. Whether it's tractors, diesels, heavy power equipment, machinery or earth movers, you will be safe with FLEX FITTINGS. Thoroughly proved by extensive use.

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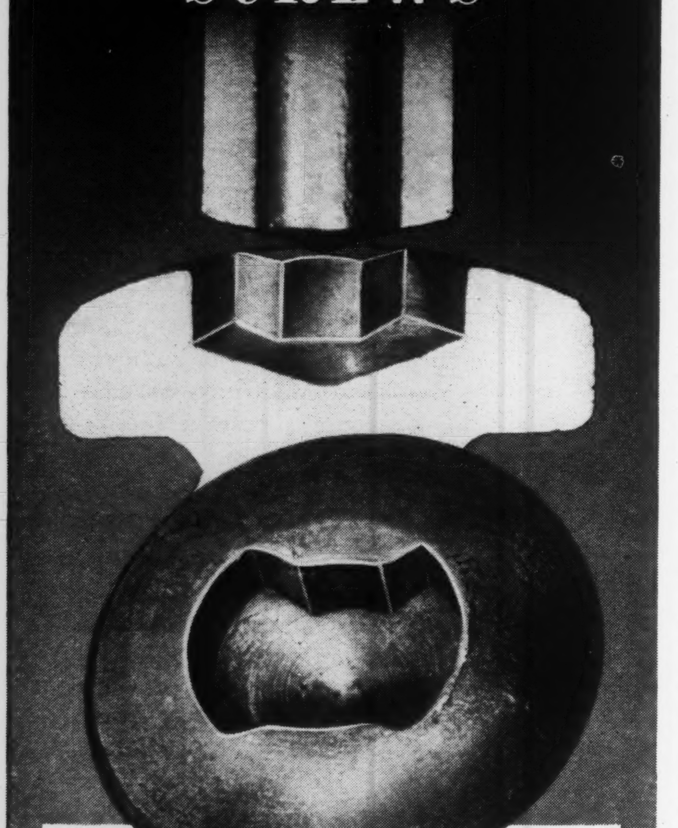

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duty. Strokes of 1 or 1¼ in. are standard; strokes to 3 in. are optional. Throat depth from center of ram hole to back is 12¾ in.; shut height with 1-in. stroke is 8½ in. to the bolster plate, adjustment up, ram down; bolster plate is 1 in. thick. Standard presses are bench models, but legs can be furnished. *Kenco Mfg. Co., Los Angeles, Calif.*

Reversing Mill: Combination two-high, four-high reversing mill can both cold reduce and skin pass either light or heavy gage material. It has two tension reels equipped with belt wrappers, base plate with integral coolant and lubrication sumps, coil box and pay-off reel. When used as a four-high mill, with 4½ and 16 x 20-in. rolls, it has driven back-up rolls, and each roll has its own individual motor without a mechanical tie-in. When used as a two-high mill, with 21 x 18 in. rolls, the same motors and drive are utilized. *Lewis Machinery Div., Blaw-Knox Co., Pittsburgh, Pa.*

Belt Grinder: Model 500 contact wheel belt grinder offers flexibilty and maneuverability in operations involving deburring, chamfering, removal of flash, fins and parting lines. It adjusts 360 deg vertically. Grinder can be mounted on a bench, pillar, portable table or other convenient place and can be used for finishing steel, cast iron, bronze, aluminum, wood and plastic parts. *B & E Mfg. Co., Kansas City, Mo.*

Plate Shear: Model 24G-8 Steelweld shear is designed for production shearing of steel plate in sizes up to 8 ft long and 1½ in. thick, at a rate of 22 strokes per minute. Shear is sturdily constructed with end housings, crown and bed welded into a solid, one-piece unit. Machine operates on pivoted-blade principle; blade travels in a circular path without use of guides and slides common with guillotine type shears, eliminating a principal source of wear and shearing inaccuracy. An electric foot switch which can be operated remotely controls the shear. Clutch and brake unit is air-operated, fast-acting and provides quick, positive clutching and braking with minimum slippage. Two counterbalances cushion blow of the shear, reducing noise. Micro-set knife adjustment facilitates adjustment of knife clearance to suit thickness of metal being cut. When hand of dial indicator reaches figure representing plate thickness, machine is ready to cut. Adjustments are provided to enable machine to perform slitting and notching operations. *Cleveland Crane & Engineering Co., Wickliffe, O.*

Pneumatic Presses: Series of air presses ranging in capacity from ¾ to 2 tons is designed for use in press-fit assembling, marking, forming, staking, light stamping and similar operations. Machine has 5-in. long side-thrust-resisting bearing, heavy-walled brass cylinder which is unaffected by moisture in line and removable base with large ground surface area to facilitate fixture mounting. Four models have cylinders of 4, 5, 6 and 7-in. bores, with power factors of 12.56, 19.63, 28.18 and 38.47 times air line pressure, respectively. The three larger models have 3 in. stroke, ¾-in. ram, 6½ in. throat depth, 9 in.

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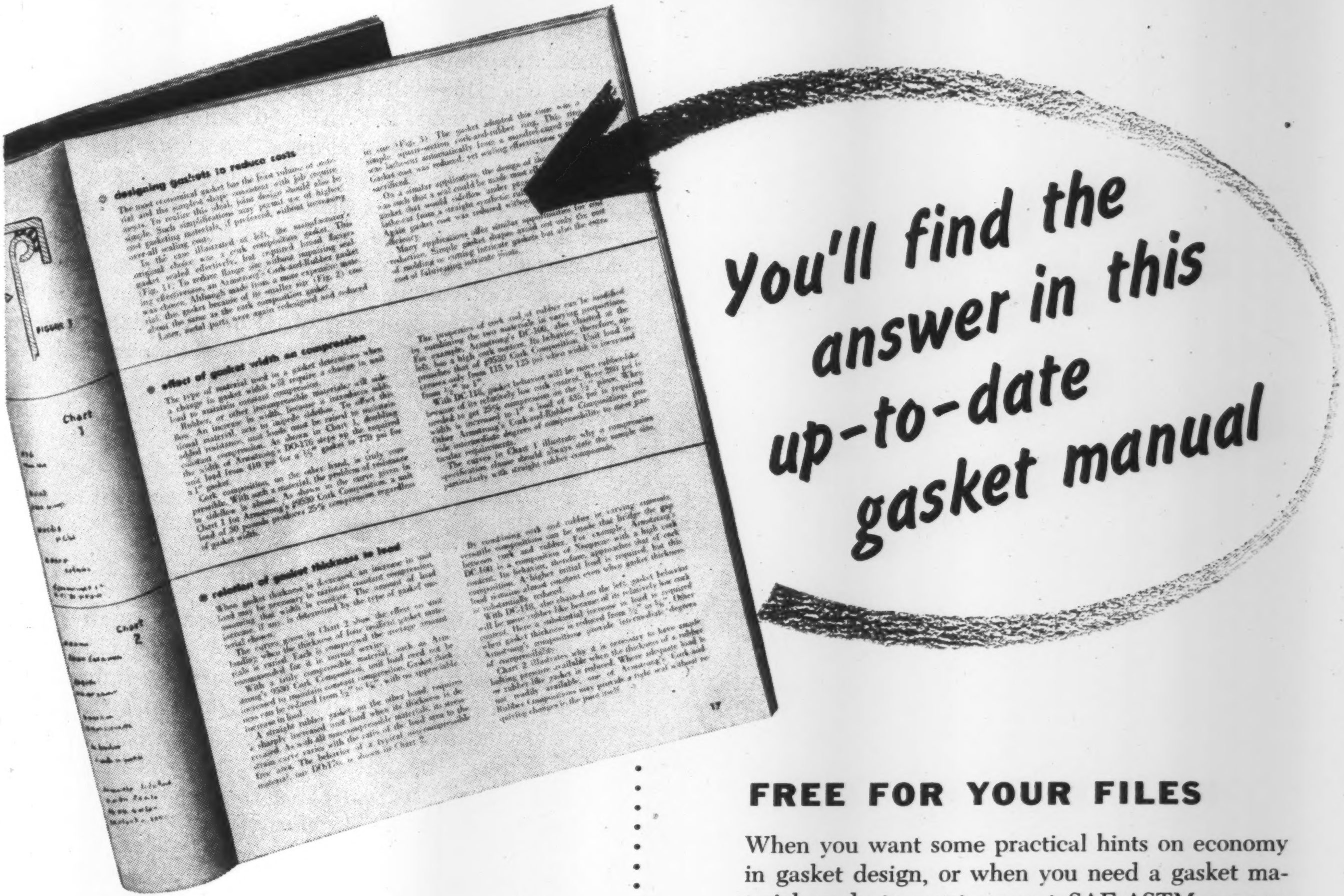
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table-to-ram height. Smallest cylinder is mounted on a lighter and slightly smaller frame. Optionally available is a series of self-aligning sub-presses which permit instant setups and setup changes. *Price Machine Products, Los Angeles, Calif.*

Rolling Mill: Two-high, four-high combination rolling mill can reduce an ingot through the sheet stage to foil. Used for bar, rod and strip reduction, it performs functions of hot flat rolling, cold flat breakdown, cold flat finishing on either a two-high or four-high setup, and hot or cold rolling of wires and shapes. To make the change from two-high to four-high large rolls are separated and two smaller work rolls are inserted between the large ones, which then become back-up rolls. Both flat and grooved rolls are available for processing round, square and other shapes. Hot rolling can be performed over a roll temperature range up to 1000 F. For heat dispersion, mill can be equipped with self-contained lubricant circulating, cooling and filtering system, and with means of circulating water through the roll interior. Machine is available in two basic sizes: 1½ in. diameter work rolls with 5 in. diameter x 8 in. face width back-up rolls or 2¼ in. with 8 x 8 in. roll sizes. *Stanat Mfg. Co., Long Island City, N. Y.*

Processing

Shell Molding Machine: Pneudralic shell molding machine makes shell molds for producing highly accurate castings having fine surface finish. Molds are 12 x 18 in. Both investing time and curing time are automatically controlled, and a radiant oven is used to heat the pattern as well as cure the shells. Dump box used for investing the pattern has a breaker screen to insure even distribution of the sand-resin mix regardless of the quantity of mix in the box. Hydraulic-air system with an accumulator is utilized to provide smooth operation of hydraulics. It operates on 80 psi compressed air. Production rate of machine is 45 to 60 shells per hour. *Centrifugal Casting Machine Co., Tulsa, Okla.*

Barrel Type Parts Cleaner: Super Barrel vapor spray degreaser rapidly cleans oily parts with non-inflammable trichlorethylene vapors. Parts are flushed with solvent by means of motor-driven pump and spray lance. Unit requires only 7 gal of solvent for operation, and dirty solvent can be reclaimed automatically and reused. Standard 55-gal galvanized drum is degreasing chamber, providing working area of 23 in. diameter with 20 in. vapor depth. Either gas or electrically heated models are available. *Baron Industries, Los Angeles, Calif.*

Vacuum Metallizer: Compact metallizer meets moderate production requirements. Model 428 has a chamber 36 in. in diameter and 60 in. long. Integral vacuum pumping system, consting of oil diffusion pump and rotary mechanical forepump, brings chamber down to metallizing pressure of 0.5-micron in about 10 minutes. Work-holding rack accommodates four standard rotating fixtures. All pushbuttons, starters, vacuum gages and rheostats are grouped in

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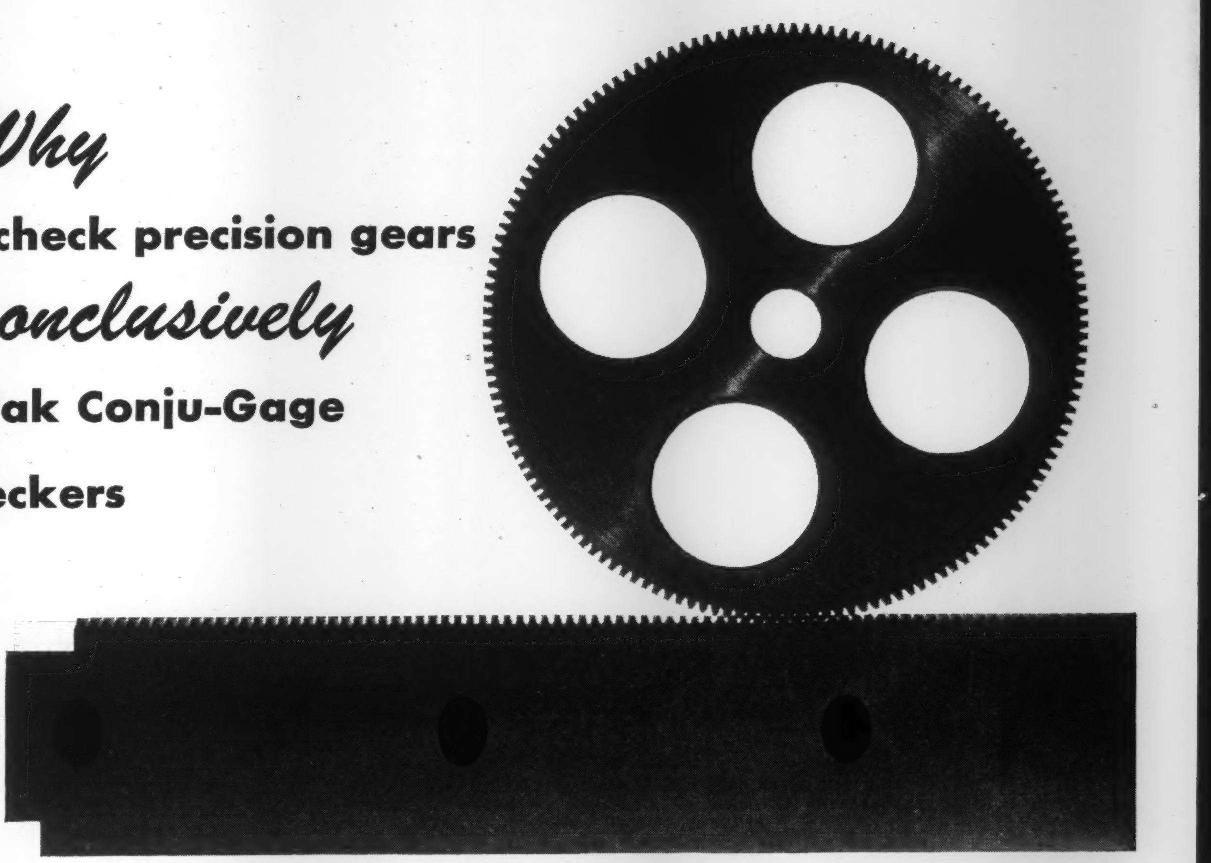
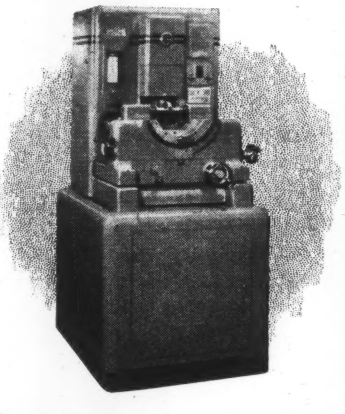


Why the composite check

Errors in gears seldom occur individually—they're usually combinations of as many as six types of errors. The practical way to test gears for these errors is to test them in action through the composite check recommended in the new American Standard (AGMA 236.02; ASA B6.11-1951).

This check measures gear errors as variations in center distance when the gear is rotated in contact with a master of known accuracy. Since this variation is the sum of errors in both gear and master, the degree of precision measurable depends on the precision of the master.



The Kodak Conju-Gage Gear Checker automatically records the composite effects of runout, base pitch error, tooth thickness variations, profile error, lead error, and lateral runout. Illustrated is the Kodak Conju-Gage Gear Checker, Model 4U, for gears up to 4⅛" pitch diameter. Larger and smaller models are also available.

Why the Conju-Gage Gear Checker

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